The Complete SPECTRUM ROM DISASSEMBLY

Dr Ian Logan & Dr Frank O'Hara

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BY

Dr Ian Logan & Dr Frank O'Hara

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Preface

The Sinclair ZX Spectrum is a worthy successor to the ZX 81 which in turn replaced the ZX 80.

The Spectrum has a 16K monitor program. This program has been developed directly from the 4K program of the ZX 80 although there are now so many new features that the differences outweigh the similarities.

We have both enjoyed producing this book. We have learnt a great deal about the techniques of Z80 machine code programming and now feel that between us we have unravelled the ‘secrets of the Spectrum’.

We would like to thank:

-- Our families.

-- Alfred Milgrom, our publisher who has been extremely helpful.

-- Philip Mitchell whose notes on the cassette format were most informative.

-- Clive Sinclair and his team at Sinclair Research Ltd. who have produced such a ‘challenging’ and useful machine.

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Contents

Introduction

The 16K monitor program of the Spectrum is a complex Z80 machine code program. Its overall structure is very clear in that it is divided into three major parts:

a. Input/Output routines
b. BASIC interpreter
c. Expression handling

However these blocks are too large to be managed easily and in this book the monitor program is discussed in ten parts.
Each of these parts will now be ‘outlined’.

The restart routines and tables.
At the start of the monitor program are the various ‘restart’ routines that are called with the single byte ‘RST’ instructions. All of the restarts are used. For example ‘restart 0008’ is used for the reporting of syntax or run-time errors.
The tables in this part of the monitor program hold the expanded forms of the tokens and the ‘key-codes’.

The keyboard routine.
The keyboard is scanned every 1/50 th. of a second (U.K. model) and the keyboard routine returns the required character code. All of the keys of the keyboard 'repeat' if they are held down and the keyboard routine takes this into consideration.

The loudspeaker routines.
The spectrum has a single on-board loudspeaker and a note is produced by repeatedly using the appropriate 'OUT' instruction. In the controller routine great care has been taken to ensure that the note is held at a given 'pitch' throughout its 'duration'.

The cassette handling routines.
It was a very unfortunate feature of the ZX 81 that so little of the monitor program for that machine was devoted to the cassette handling.
However in the Spectrum there is an extensive block of code and now the high standard of cassette handling is one of the most successful features of the machine.
BASIC programs or blocks of data are both dealt with in the same manner of having a 'header' block (seventeen bytes) that is SAVEd first. This 'header' describes the 'data block' that is SAVEd after it.
One disadvantage of this system is that it is not possible to produce programs with any 'security' whatsoever.

The screen and printer handling routines.
All of the remaining input/output routines of the Spectrum are 'vectored' through the 'channel & stream information areas'.
In the standard Spectrum 'input' is only possible from the keyboard but 'output' can be directed to the printer, the upper part of the T.V. display or the lower part of the T.V. display.
The major 'input' routine in this part of the monitor program is the EDITOR that allows the user to enter characters into the lower part of the T.V. display.
The PRINT-OUT routine is a rather slow routine as the same routine is used for 'all possibilities'. For example, the adding of a single byte to the 'display area' involves considering the present status of OVER and INVERSE on every occasion.

The executive routines
In this part of the monitor program are to be found the INITIALISATION procedure and the 'main execution loop' of the BASIC interpreter.
In the Spectrum the BASIC line returned by the EDITOR is checked for the correctness of its syntax and then saved in the program area, if it was a line starting with a line number, or 'executed' otherwise.
This execution can in turn lead to further statements being considered. (Most clearly seen as in the case of - RUN.)

BASIC line and command interpretation.
This part of the monitor program considers a BASIC line as a set of statements and in its turn each statement as starting with a particular command. For each command there is a 'command routine' and it is the execution of the machine code in the appropriate 'command routine' that effects the 'interpretation'.

Expression evaluation
The Spectrum has a most comprehensive expression evaluator allowing for a wide range of variable types, functions and operations. Once again this part of the monitor is fairly slow as all the possible alternatives have to be considered.
The handling of strings is particularly well managed. All simple strings are managed 'dynamically' and old copies are 'reclaimed' once they are redundant. This means that there is no 'garbage collecting' to be done.

The arithmetic routines
The Spectrum has two forms for numbers. Integer values in the range -65535 to +65535 are in an 'integral' or 'short' form whilst all other numbers are in a five byte floating point form.
The present version of the monitor is unfortunately marred by two mistakes in this part.
i. There is a mistake in 'division' whereby the 34th bit of a division is lost.
ii. The value of -65536 is sometimes put in 'short' form and at other times in 'floating-point' and this leads to troubles.

The floating-point calculator
The CALCULATOR of the Spectrum handles numbers and strings and its operations are specified by 'literals'. It can therefore be considered that there is an internal 'stack operating' language in the CALCULATOR.
This part of the monitor program contains routines for all the mathematical functions. The approximations to SIN X, EXP X, LN X & ATN X are obtained by developing Chebyshev polynomials and full details are given in the appendix.

Overall the 16K monitor program offers an extremely wide range of different BASIC commands and functions. The programmers have always however been short of 'room' and hence the program is written for 'compactness' rather than 'speed'.

THE DISASSEMBLY

THE RESTART ROUTINES and THE TABLES

THE 'START'

The maskable interrupt is disabled and the DE register pair set to hold the 'top of possible RAM'.

```
0000    START       DI                          Disable the 'keyboard interrupt'.
                    XOR         A               +00 for start (but +FF for
                                                'NEW').
                    LD          DE,+FFFF        Top of possible RAM.
                    JP          11CB,START/NEW  Jump forward.
```

THE 'ERROR' RESTART

The error pointer is made to point to the position of the error.

```
0008    ERROR-1     LD          HL,(CH-ADD)     The address reached by the
                    LD          (X-PTR),HL      interpreter is copied to the error
                    JP          0053,ERROR-2    pointer before proceeding.
```

THE 'PRINT A CHARACTER' RESTART

The A register holds the code of the character that is to be printed.

```
0010    PRINT-A-1   JP          15F2,PRINT-A-2  Jump forward immediately.
                    DEFB        +FF,+FF,+FF,+FF,+FF  Unused locations.
```

THE 'COLLECT CHARACTER' RESTART

The contents of the location currently addressed by CH-ADD are fetched. A return is made if the value represents a printable character, otherwise CH-ADD is incremented and the tests repeated.

```
0018    GET-CHAR    LD          HL,(CH-ADD)     Fetch the value that is addressed
                    LD          A,(HL)          by CH-ADD.
001C    TEST-CHAR   CALL        007D,SKIP-OVER  Find out if the character is
                    RET         NC              printable. Return if it is so.
```

THE 'COLLECT NEXT CHARACTER' RESTART

As a BASIC line is interpreted, this routine is called repeatedly to step along the line.

```
0020    NEXT-CHAR   CALL        0074,CH-ADD+1   CH-ADD needs to be incre-
                                                mented.
                    JR          001C,TEST-CHAR  Jump back to test the new
                                                value.
                    DEFB        +FF,+FF,+FF     Unused locations.
```

THE 'CALCULATOR' RESTART

The floating point calculator is entered at 335B.

```
0028    FP-CALC     JP          335B,CALCULATE  Jump forward immediately.
                    DEFB        +FF,+FF,+FF,+FF,+FF  Unused locations.
```

THE 'MAKE BC SPACES' RESTART

This routine creates free locations in the work space. The number of locations is determined by the current contents of the BC register pair.

```
0030    BC-SPACES   PUSH        BC              Save the 'number'.
                    LD          HL,(WORKSP)     Fetch the present address of the
                    PUSH        HL              start of the work space and save
                    JP          169E,RESERVE    that also before proceeding.
```

THE 'MASKABLE INTERRUPT' ROUTINE

The real time clock is incremented and the keyboard scanned whenever a maskable interrupt occurs.

```
0038    MASK-INT    PUSH        AF              Save the current values held in
                    PUSH        HL              these registers.
                    LD          HL,(FRAMES)     The lower two bytes of the
```

```
                INC     HL              frame counter are incremented
                LD      (FRAMES),HL     every 20 ms. (U.K.) The highest
                LD      A,H             byte of the frame counter is
                OR      L               only incremented when the
                JR      NZ,0048,KEY-INT value of the lower two bytes
                INC     (FRAMES-3)      is zero.
0048    KEY-INT PUSH    BC              Save the current values held
                PUSH    DE              in these registers.
                CALL    02BF,KEYBOARD   Now scan the keyboard.
                POP     DE              Restore the values.
                POP     BC
                POP     HL
                POP     AF
                EI                      The maskable interrupt is en-
                RET                     abled before returning.
```

THE 'ERROR-2' ROUTINE

The return address to the interpreter points to the 'DEFB' that signifies which error has occurred. This 'DEFB' is fetched and transferred to ERR-NR. The machine stack is cleared before jumping forward to clear the calculator stack.

```
0053    ERROR-2 POP     HL              The address on the stack points
                LD      L,(HL)          to the error code.
0055    ERROR-3 LD      (ERR-NR),L      It is transferred to ERR-NR.
                LD      SP,(ERR-SP)     The machine is cleared before
                JP      16C5,SET-STK    exiting via SET-STK.
                DEFB    +FF,+FF,+FF,+FF Unused locations.
                DEFB    +FF,+FF,+FF
```

THE 'NON-MASKABLE INTERRUPT' ROUTINE

This routine is not used in the standard Spectrum but the code allows for a system reset to occur following activation of the NMI line. The system variable at 5CB0, named here NMIADD, has to have the value zero for the reset to occur.

```
0066    RESET   PUSH    AF              Save the current values held
                PUSH    HL              in these registers.
                LD      HL,(NMIADD)     The two bytes of NMIADD
                LD      A,H             must both be zero for the reset
                OR      L               to occur.
                JR      NZ,0070,NO-RESET Note: This should have been
                                        'JR Z'!
                JP      (HL)            Jump to START.
0070    NO-RESET POP    HL              Restore the current values to
                POP     AF              these registers and return.
                RETN
```

THE 'CH-ADD+1' SUBROUTINE

The address held in CH-ADD is fetched, incremented and restored. The contents of the location now addressed by CH-ADD is fetched. The entry points of TEMP-PTR1 and TEMP-PTR2 are used to set CH-ADD for a temporary period.

```
0074    CH-ADD+1  LD    HL,(CH-ADD)     Fetch the address.
0077    TEMP-PTR1 INC   HL              Increment the pointer.
0078    TEMP-PTR2 LD    (CH-ADD),HL     Set CH-ADD.
                  LD    A,(HL)          Fetch he addressed value and
                  RET                   then return.
```

THE 'SKIP-OVER' SUBROUTINE

The value brought to the subroutine in the A register is tested to see if it is printable. Various special codes lead to HL being incremented once, or twice, and CH-ADD amended accordingly.

```
007D    SKIP-OVER CP    +21             Return with the carry flag reset
                  RET   NC              if ordinary character code.
                  CP    +0D             Return if the end of the line
                  RET   Z               has been reached.
                  CP    +10             Return with codes +00 to +0F
```

```
                    RET         C               but with carry set.
                    CP          +18             Return with codes +18 to +20
                    CCF                         again with carry set.
                    RET         C
                    INC         HL              Skip-over once.
                    CP          +16             Jump forward with codes +10
                    JR          C,0090,SKIPS    to +15 (INK to OVER).
                    INC         HL              Skip-over once more (AT &
                                                TAB).
0090    SKIPS       SCF                         Return with the carry flag set
                    LD          (CH-ADD),HL     and CH-ADD holding the
                    RET                         appropriate address.
```

THE TOKEN TABLE

All the tokens used by the Spectrum are expanded by reference to this table. The last code of each token is 'inverted' by having its bit 7 set.

```
0095  BF 52 4E C4 49 4E 4B 45     '?' R  N 'D' I  N  K  E
009D  59 A4 50 C9 46 CE 50 4F      Y '$' P 'I' F 'N' P  O
00A5  49 4E D4 53 43 52 45 45      I  N 'T' S  C  R  E  E
00AD  4E A4 41 54 54 D2 41 D4      N '$' A  T  T 'R' A 'T'
00B5  54 41 C2 56 41 4C A4 43      T  A 'B' V  A  L '$' C
00BD  4F 44 C5 56 41 CC 4C 45      O  D 'E' V  A 'L' L  E
00C5  CE 53 49 CE 43 4F D3 54     'N' S  I 'N' C  O 'S' T
00CD  41 CE 41 53 CE 41 43 D3      A 'N' A  S 'N' A  C 'S'
00D5  41 54 CE 4C CE 45 58 D0      A  T 'N' L 'N' E  X 'P'
00DD  49 4E D4 53 51 D2 53 47      I  N 'T' S  Q 'R' S  G
00E5  CE 41 42 D3 50 45 45 CB     'N' A  B 'S' P  E  E 'K'
00ED  49 CE 55 53 D2 53 54 52      I 'N' U  S 'R' S  T  R
00F5  A4 43 48 52 A4 4E 4F D4     '$' C  H  R '$' N  O 'T'
00FD  42 49 CE 4F D2 41 4E C4      B  I 'N' O 'R' A  N 'D'
0105  3C BD 3E BD 3C BE 4C 49      <  '=' >  '=' <  '>' L  I
010D  4E C5 54 48 45 CE 54 CF      N 'E' T  H  E 'N' T 'O'
0115  53 54 45 D0 44 45 46 20      S  T  E 'P' D  E  F
011D  46 CE 43 41 D4 46 4F 52      F 'N' C  A 'T' F  O  R
0125  4D 41 D4 4D 4F 56 C5 45      M  A 'T' M  O  V 'E' E
012D  52 41 53 C5 4F 50 45 4E      R  A  S 'E' O  P  E  N
0135  20 A3 43 4C 4F 53 45 20        '#' C  L  O  S  E
013D  A3 4D 45 52 47 C5 56 45     '#' M  E  R  G 'E' V  E
0145  52 49 46 D9 42 45 45 D0      R  I  F 'Y' B  E  E 'P'
014D  43 49 52 43 4C C5 49 4E      C  I  R  C  L 'E' I  N
0155  CB 50 41 50 45 D2 46 4C     'K' P  A  P  E 'R' F  L
015D  41 53 C8 42 52 49 47 48      A  S 'H' B  R  I  G  H
0165  D4 49 4E 56 45 52 53 C5     'T' I  N  V  E  R  S 'E'
016D  4F 56 45 D2 4F 55 D4 4C      O  V  E 'R' O  U 'T' L
0175  50 52 49 4E D4 4C 4C 49      P  R  I  N 'T' L  L  I
017D  53 D4 53 54 4F D0 52 45      S 'T' S  T  O 'P' R  E
0185  41 C4 44 41 54 C1 52 45      A 'D' D  A  T 'A' R  E
018D  53 54 4F 52 C5 4E 45 D7      S  T  O  R 'E' N  E 'W'
0195  42 4F 52 44 45 D2 43 4F      B  O  R  D  E 'R' C  O
019D  4E 54 49 4E 55 C5 44 49      N  T  I  N  U 'E' D  I
01A5  CD 52 45 CD 46 4F D2 47     'M' R  E 'M' F  O 'R' G
01AD  4F 20 54 CF 47 4F 20 53      O     T 'O' G  O     S
01B5  55 C2 49 4E 50 55 D4 4C      U 'B' I  N  P  U 'T' L
01BD  4F 41 C4 4C 49 53 D4 4C      O  A 'D' L  I  S 'T' L
01C5  45 D4 50 41 55 53 C5 4E      E 'T' P  A  U  S 'E' N
01CD  45 58 D4 50 4F 4B C5 50      E  X 'T' P  O  K 'E' P
01D5  52 49 4E D4 50 4C 4F D4      R  I  N 'T' P  L  O 'T'
01DD  52 55 CE 53 41 56 C5 52      R  U 'N' S  A  V 'E' R
01E5  41 4E 44 4F 4D 49 5A C5      A  N  D  O  M  I  Z 'E'
01ED  49 C6 43 4C D3 44 52 41      I 'F' C  L 'S' D  R  A
01F5  D7 43 4C 45 41 D2 52 45     'W' C  L  E  A 'R' R  E
01FD  54 55 52 CE 43 4F 50 D9      T  U  R 'N' C  O  P 'Y'
```

THE KEY TABLES

There are six separate key tables. The final character code obtained depends on the particular key pressed and the 'mode' being used.

(a) The main key table - L mode and CAPS SHIFT.

```
0205  42 48 59 36 35 54 47 56        B      H    Y  6  5  T  G  V
020D  4E 4A 55 37 34 52 46 43        N      J    U  7  4  R  F  C
0215  4D 4B 49 38 33 45 44 58        M      K    I  8  3  E  D  X
021D  0E 4C 4F 39 32 57 53 5A     SYMBOL    L    0  9  2  W  S  Z
                                  SHIFT
0225  20 0D 50 30 31 51 41        SPACE   ENTER  P  0  1  Q  A
```

(b) Extended mode. Letter keys and unshifted

```
022C  E3 C4 E0 E4    READ      BIN       LPRINT    DATA
0230  B4 BC BD BB    TAN       SGN       ABS       SQR
0234  AF B0 B1 C0    CODE      VAL       LEN       USR
0238  A7 A6 BE AD    PI        INKEY$    PEEK      TAB
023C  B2 BA E5 A5    SIN       INT       RESTORE   RND
0240  C2 E1 B3 B9    CHR$      LLIST     COS       EXP
0244  C1 B8          STR$      LN
```

(c) Extended mode. Letter keys and either shift.

```
0246  7E DC DA 5C    ~         BRIGHT    PAPER     \
024A  B7 7B 7D D8    ATN       {         }         CIRCLE
024E  BF AE AA AB    IN        VAL$      SCREEN$   ATTR
0252  DD DE DF 7F    INVERSE   OVER      OUT       ©
0256  B5 D6 7C D5    ASN       VERIFY    |         MERGE
025A  5D DB B6 D9    ]         FLASH     ACS       INK
025E  5B D7 0C 07    [         BEEP
```

(d) Control codes. Digit keys and CAPS SHIFT.

```
0260  0C 07 06 04    DELETE          EDIT          CAPS LOCK    TRUE VIDEO
0264  05 08 0A 0B    INV VIDEO       Cursor left   Cursor down  Cursor up
0268  09 0F          Cursor right    GRAPHICS
```

(e) Symbol code. Letter keys and symbol shift.

```
026A  E2 2A 3F CD    STOP      *         ?         STEP
026E  C8 CC CB 5E    >=        TO        THEN      ^
0272  AC 2D 2B 3D    AT        -         +         =
0276  2E 2C 3B 22    .         ,         ;         "
027A  C7 3C C3 3E    <=        <         NOT       >
027E  C5 2F C9 60    OR        /         <>        £
0282  C6 3A          AND       :
```

(f) Extended mode. Digit keys and symbol shift.

```
0284  D0 CE A8 CA    FORMAT    DEF FN    FN        LINE
0288  D3 D4 D1 D2    OPEN      CLOSE     MOVE      ERASE
028C  A9 CF          POINT     CAT
```

THE KEYBOARD ROUTINES

THE 'KEYBOARD SCANNING' SUBROUTINE

This very important subroutine is called by both the main keyboard subroutine and the INKEY$ routine (in SCANNING).
In all instances the E register is returned with a value in the range of +00 to +27, the value being different for each of the forty keys of the keyboard, or the value +FF, the no-key.
The D register is returned with a value that indicates which single shift key is being pressed. If both shift keys are being pressed then the D and E registers are returned with the values for the CAPS SHIFT and SYMBOL SHIFT keys respectively.
If no keys is being pressed then the DE register pair is returned holding +FFFF.
The zero flag is returned reset if more than two keys are being pressed, or neither key of a pair of keys is a shift key.

028E	KEY-SCAN	LD	L,+2F	The initial key value for each line will be +2F, +2E,...,+28. (Eight lines.)
		LD	DE,+FFFF	Initialise DE to 'no-key'.
		LD	BC,+FEFE	C = port address, B = counter.

Now enter a loop. Eight passes are made with each pass having a different initial key value and scanning a different line of five keys. (The first line is CAPS SHIFT, Z, X, C, V.)

0296	KEY-LINE	IN	A,(C)	Read from the port specified.
		CPL		A pressed key in the line will set
		AND	+1F	its respective bit (from bit 0 - outer key, to bit 4 - inner key).
		JR	Z,02AB,KEY-DONE	Jump forward if none of the five keys in the line are being pressed.
		LD	H,A	The key-bits go to the H register
		LD	A,L	whilst the initial key value is fetched.
029F	KEY-3KEYS	INC	D	If three keys are being pressed
		RET	NZ	on the keyboard then the D register will no longer hold +FF - so return if this happens.
02A1	KEY-BITS	SUB	+08	Repeatedly subtract '8' from
		SRL	H	the preset key value until a
		JR	NC,02A1,KEY-BITS	key-bit is found.
		LD	D,E	Copy any earlier key value to the D register.
		LD	E,A	Pass the new key value to the E register.
		JR	NZ,029F,KEY-3KEYS	If there is a second, or possibly a third, pressed key in this line then jump back.
02AB	KEY-DONE	DEC	L	The line has been scanned so the initial key value is reduced for the next pass.
		RLC	B	The counter is shifted and the
		JR	C,0296,KEY-LINE	jump taken if there are still lines to be scanned.
Four tests are now made.				
		LD	A,D	Accept any key value for a pair
		RET	Z	of keys if the 'D' key is CAPS SHIFT.

```
                CP      +19             Accept the key value for a pair
                RET     Z               of keys if the 'D' key is SYMBOL
                                        SHIFT.
                LD      A,E             It is however possible for the 'E'
                LD      E,D             key of a pair to be SYMBOL
                LD      D,A             SHIFT - so this has to be
                CP      +18             considered.
                RET                     Return with the zero flag set if
                                        it was SYMBOL SHIFT and
                                        'another key'; otherwise reset.
```

THE 'KEYBOARD' SUBROUTINE

This subroutine is called on every occasion that a maskable interrupt occurs. In normal operation this will happen once every 20 ms. The purpose of this subroutine is to scan the keyboard and decode the key value. The code produced will, if the 'repeat' status allows it, be passed to the system variable LAST-K. When a code is put into this system variable bit 5 of FLAGS is set to show that a 'new' key has been pressed.

```
02BF    KEYBOARD    CALL    028E,KEY-SCAN   Fetch a key value in the DE
                    RET     NZ              register pair but return immedi-
                                            ately if the zero pair flag is reset.
```

A double system of 'KSTATE system variables' (KSTATE0 - KSTATE 3 and KSTATE4 - KSTATE7) is used from now on.
The two sets allow for the detection of a new key being pressed (using one set) whilst still within the 'repeat period' of the previous key to have been pressed (details in the other set).
A set will only become free to handle a new key if the key is held down for about 1/10 th. of a second. i.e. Five calls to KEYBOARD.

```
                    LD      HL,KSTATE0      Start with KSTATE0.
02C6    K-ST-LOOP   BIT     7,(HL)          Jump forward if a 'set is free';
                    JR      NZ,02D1,K-CH-SET  i.e. KSTATE0/4 holds +FF.
                    INC     HL              However if the set is not free
                    DEC     (HL)            decrease its '5 call counter'
                    DEC     HL              and when it reaches zero signal
                    JR      NZ,02D1,K-CH-SET  the set as free.
                    LD      (HL),+FF
```

After considering the first set change the pointer and consider the second set.

```
02D1    K-CH-SET    LD      A,L             Fetch the low byte of the
                    LD      HL,+KSTATE4     address and jump back if the
                    CP      L               second set has still to be
                    JR      NZ,02C6,K-ST-LOOP  considered.
```

Return now if the key value indicates 'no-key' or a shift key only.

```
                    CALL    031E,K-TEST     Make the necessary tests and
                    RET     NC              return if needed. Also change
                                            the key value to a 'main code'.
```

A key stroke that is being repeated (held down) is now separated from a new key stroke.

```
                    LD      HL,+KSTATE0     Look first at KSTATE0.
                    CP      (HL)            Jump forward if the codes
                    JR      Z,0310,K-REPEAT match - indicating a repeat.
                    EX      DE,HL           Save the address of KSTATE0.
                    LD      HL,+KSTATE4     Now look at KSTATE4.
                    CP      (HL)            Jump forward if the codes
                    JR      Z,0310,K-REPEAT match - indicating a repeat.
```

But a new key will not be accepted unless one of the sets of KSTATE system variables is 'free'.

```
                    BIT     7,(HL)          Consider the second set.
                    JR      NZ,02F1,K-NEW   Jump forward if 'free'.
                    EX      DE,HL           Now consider the first set.
```

```
                BIT     7,(HL)          Continue if the set is 'free' but
                RET     Z               exit from the KEYBOARD
                                        subroutine if not.
```

The new key is to be accepted. But before the system variable LAST-K can be filled, the KSTATE system variables, of the set being used, have to be initialised to handle any repeats and the key's code has to be decoded.

```
02F1    K-NEW   LD      E,A             The code is passed to the
                LD      (HL),A          E register and to KSTATE0/4.
                INC     HL              The '5 call counter' for this
                LD      (HL),+05        set is reset to '5'.
                INC     HL              The third system variable of
                LD      A,(REPDEL)      the set holds the REPDEL value
                LD      (HL),A          (normally 0.7 secs.).
                INC     HL              Point to KSTATE3/7.
```

The decoding of a 'main code' depends upon the present state of MODE, bit 3 of FLAGS and the 'shift byte'.

```
                LD      C,(MODE)        Fetch MODE.
                LD      D,(FLAGS)       Fetch FLAGS.
                PUSH    HL              Save the pointer whilst the
                CALL    0333,K-DECODE   'main code' is decoded.
                POP     HL
                LD      (HL),A          The final code value is saved in
                                        KSTATE3/7; from where it is
                                        collected in case of a repeat.
```

The next three instruction lines are common to the handling of both 'new keys' and 'repeat keys'.

```
0308    K-END   LD      (LAST-K),A      Enter the final code value into
                SET     5,(FLAGS)       LAST-K and signal 'a new key'.
                RET                     Finally return.
```

THE 'REPEATING KEY' SUBROUTINE

A key will 'repeat' on the first occasion after the delay period - REPDEL (normally 0.7 secs.) and on subsequent occasions after the delay period - REPPER (normally 0.1 secs.).

```
0310    K-REPEAT INC    HL              Point to the '5 call counter'
                LD      (HL),+05        of the set being used and reset
                                        it to '5'.
                INC     HL              Point to the third system vari-
                DEC     (HL)            able - the REPDEL/REPPER
                                        value, and decrement it.
                RET     NZ              Exit from the KEYBOARD
                                        subroutine if the delay period
                                        has not passed.
                LD      A,(REPPER)      However once it has passed the
                LD      (HL),A          delay period for the next repeat
                                        is to be REPPER.
                INC     HL              The repeat has been accepted
                LD      A,(HL)          so the final code value is fetched
                                        from KSTATE3/7 and passed
                JR      0308,K-END      to K-END.
```

THE 'K-TEST' SUBROUTINE

The key value is tested and a return made if 'no-key' or 'shift-only'; otherwise the 'main code' for that key is found.

```
031E    K-TEST  LD      B,D             Copy the shift byte.
                LD      D,+00           Clear the D register for later.
                LD      A,E             Move the key number.
                CP      +27             Return now if the key was
                RET     NC              'CAPS SHIFT' only or 'no-key'.
```

```
                CP      +18             Jump forward unless the 'E'
                JR      NZ,032C,K-MAIN  key was SYMBOL SHIFT.
                BIT     7,B             However accept SYMBOL SHIFT
                RET     NZ              and another key; return with
                                        SYMBOL SHIFT only.
```

The 'main code' is found by indexing into the main key table.

```
032C  K-MAIN    LD      HL,+0205        The base address of the table.
                ADD     HL,DE           Index into the table and fetch
                LD      A,(HL)          the 'main code'.
                SCF                     Signal 'valid keystroke'
                RET                     before returning.
```

THE 'KEYBOARD DECODING' SUBROUTINE

This subroutine is entered with the 'main code' in the E register, the value of FLAGS in the D register, the value of MODE in the C register and the 'shift byte' in the B register.
By considering these four values and referring, as necessary, to the six key tables a 'final code' is produced. This is returned in the A register.

```
0333  K-DECODE  LD      A,E             Copy the 'main code'.
                CP      +3A             Jump forward if a digit key is
                JR      C,0367,K-DIGIT  being considered; also SPACE,
                                        ENTER & both shifts.
                DEC     C               Decrement the MODE value.
                JP      M,034F,K-KLC-LET Jump forward, as needed, for
                JR      Z,0341,K-E-LET  modes 'K', 'L', 'C' & 'E'.
```

Only 'graphics' mode remains and the 'final code' for letter keys in graphics mode is computed from the 'main code'.

```
                ADD     A,+4F           Add the offset.
                RET                     Return with the 'final code'.
```

Letter keys in extended mode are considered next.

```
0341  K-E-LET   LD      HL,+01EB        The base address for table 'b'.
                INC     B               Jump forward to use this table
                JR      Z,034A,K-LOOK-UP if neither shift key is being
                                        pressed.
                LD      HL,+0205        Otherwise use the base address
                                        for table 'c'.
```

Key tables 'b-f' are all served by the following look-up routine. In all cases a 'final code' is found and returned.

```
034A  K-LOOK-UP LD      D,+00           Clear the D register.
                ADD     HL,DE           Index the required table
                LD      A,(HL)          and fetch the 'final code'.
                RET                     Then return.
```

Letter keys in 'K', 'L' or 'C' modes are now considered. But first the special SYMBOL SHIFT codes have to be dealt with.

```
034F  K-KLC-LET LD      HL,+0229        The base address for table 'e'
                BIT     0,B             Jump back if using the SYMBOL
                JR      Z,034A,K-LOOK-UP SHIFT key and a letter key.
                BIT     3,D             Jump forward if currently in
                JR      Z,0364,K-TOKENS 'K' mode.
                BIT     3,(FLAGS2)      If CAPS LOCK is set then
                RET     NZ              return with the 'main code'
                INC     B               Also return in the same manner
                RET     NZ              if CAPS SHIFT is being pressed.
                ADD     A,+20           However if lower case codes are
                RET                     required then +20 has to be
                                        added to the 'main code' to give
                                        the correct 'final code'.
```

The 'final code' values for tokens are found by adding +A5 to the 'main code'.

```
0364    K-TOKENS    ADD     A,+A5           Add the required offset and
                    RET                     return.
```

Next the digit keys; and SPACE, ENTER & both shifts; are considered.

```
0367    K-DIGIT     CP      +30             Proceed only with the digit keys.
                    RET     C               i.e. Return with SPACE (+20),
                                            ENTER (+0D) & both shifts
                                            (+0E).
                    DEC     C               Now separate the digit keys into
                                            three groups - according to the
                                            mode.
                    JP      M,039D,K-KLC-DGT Jump with 'K', 'L' & 'C' modes;
                    JR      NZ,0389,K-GRA-DGT and also with 'G' mode.
                                            Continue with 'E' mode.
                    LD      HL,+0254        The base address for table 'f'.
                    BIT     5,B             Use this table for SYMBOL
                    JR      Z,034A,K-LOOK-UP SHIFT & a digit key in
                                            extended mode.
                    CP      +38             Jump forward with digit keys
                    JR      NC,0382,K-8-&-9 '8' and '9'.
```

The digit keys '0' to '7' in extended mode are to give either a 'paper colour code' or an 'ink colour code' depending on the use of the CAPS SHIFT.

```
                    SUB     +20             Reduce the range +30 to +37
                                            giving +10 to +17.
                    INC     B               Return with this 'paper colour
                    RET     Z               code' if the CAPS SHIFT is
                                            not being used.
                    ADD     A,+08           But if it is then the range is to
                    RET                     be +18 to +1F instead - indicat-
                                            ing an 'ink colour code'.
```

The digit keys '8' and '9' are to give 'BRIGHT' & 'FLASH' codes.

```
0382    K-8-&-9     SUB     +36             +38 & +39 go to +02 & +03.
                    INC     B               Return with these codes if CAPS
                    RET     Z               SHIFT is not being used. (These
                                            are 'BRIGHT' codes.)
                    ADD     A,+FE           Subtract '2' is CAPS SHIFT is
                    RET                     being used; giving +00 & +01 (as
                                            'FLASH' codes).
```

The digit keys in graphics mode are to give the block graphic characters (+80 to +8F), the GRAPHICS code (+0F) and the DELETE code (+0C).

```
0389    K-GRA-DGT   LD      HL,+0230        The base address of table 'd'.
                    CP      +39             Use this table directly for
                    JR      Z,034A,K-LOOK-UP both digit key '9' that is to give
                    CP      +30             GRAPHICS, and digit key '0'
                    JR      Z,034A,K-LOOK-UP that is to give DELETE.
                    AND     +07             For keys '1' to '8' make the
                    ADD     A,+80           range +80 to +87.
                    INC     B               Return with a value from this
                    RET     Z               range if neither shift key is
                                            being pressed.
                    XOR     +0F             But if 'shifted' make the range
                    RET                     +88 to +8F.
```

Finally consider the digit keys in 'K', 'L' & 'C' modes.

```
039D    K-KLC-DGT   INC     B               Return directly if neither shift
                    RET     Z               key is being used. (Final codes
                                            +30 to +39.)
                    BIT     5,B             Use table 'd' if the CAPS
                    LD      HL,+0230        SHIFT key is also being
                    JR      NZ,034A,K-LOOK-UP pressed.
```

The codes for the various digit keys and SYMBOL SHIFT can now be found.

```
                    SUB     +10         Reduce the range to give +20 to
                                        +29.
                    CP      +22         Separate the '@' character
                    JR      Z,03B2,K-@-CHAR from the others.
                    CP      +20         The '-' character has also to be
                                        separated.
                    RET     NZ          Return now with the 'final
                                        codes' +21, +23 to +29.
                    LD      A,+5F       Give the '-' character a
                    RET                 code of +5F.
03B2    K-@-CHAR    LD      A,+40       Give the '@' character a code
                    RET                 of +40.
```

THE LOUDSPEAKER ROUTINES

The two subroutines in this section are the BEEPER subroutine, that actually controls the loudspeaker, and the BEEP command routine.
The loudspeaker is activated by having D4 low during an OUT instruction that is using port '254'. When D4 is high in a similar situation the loudspeaker is deactivated. A 'beep' can therefore be produced by regularly changing the level of D4.
Consider now the note 'middle C' which has the frequency 261.63 hz. In order to get this note the loudspeaker will have to be alternately activated and deactivated every 1/523.26th. of a second. In the SPECTRUM the system clock is set to run at 3.5 mhz. and the note of 'middle C' will require that the requisite OUT instruction be executed as close as possible to every 6,689 T states. This last value, when reduced slightly for unavoidable overheads, represents the 'length of the timing loop' in the BEEPER subroutine.

THE 'BEEPER' SUBROUTINE

This subroutine is entered with the DE register pair holding the value 'f*t', where a note of given frequency 'f' is to have a duration of 't' seconds, and the HL register pair holding a value equal to the number of T states in the 'timing loop' divided by '4'.
i.e. For the note 'middle C' to be produced for one second DE holds +0105 (INT(261.3 * 1)) and HL holds +066A (derived from 6,689/4 - 30.125).

```
03B5    BEEPER      DI                          Disable the interrupt for the
                                                duration of a 'beep'.
                    LD          A,L             Save L temporarily.
                    SRL         L               Each '1' in the L register is
                    SRL         L               to count '4' T states, but take
                                                INT (L/4) and count '16' T
                                                states instead.
                    CPL                         Go back to the original value
                    AND         +03             in L and find how many were
                    LD          C,A             lost by taking INT (L/4).
                    LD          B,+00
                    LD          IX,+03D1        The base address of the timing
                                                loop.
                    ADD         IX,BC           Alter the length of the timing
                                                loop. Use an earlier starting
                                                point for each '1' lost by taking
                                                INT (L/4).
                    LD          A,(BORDCR)      Fetch the present border
                    AND         +38             colour and move it to bits
                    RRCA                        2, 1 & 0 of the A register.
                    RRCA
                    RRCA
                    OR          +08             Ensure the MIC output is 'off'.
```

Now enter the sound generation loop. 'DE' complete passes are made, i.e. a pass for each cycle of the note.
The HL register holds the 'length of the timing loop' with '16' T states being used for each '1' in the L register and '1,024' T states for each '1' in the H register.

```
03D1    BE-IX+3     NOP                         Add '4' T states for each
03D2    BE-IX+2     NOP                         earlier entry port
03D3    BE-IX+1     NOP                         that is used.
03D4    BE-IX+0     INC         B               The values in the B & C registers
                    INC         C               will come from H & L registers
                                                - see below.
03D6    BE-H&L-LP   DEC         C               The 'timing loop'.
                    JR          NZ,03D6,BE-H&L-LP   i.e. 'BC' * '4' T states.
                    LD          C,+3F           (But note that at the half-cycle
                    DEC         B               point - C will be equal to
                    JP          NZ,03D6,BE-H&L-LP   'L+1'.)
```

The loudspeaker is now alternately activated and deactivated.

```
                    XOR         +10             Flip bit 4.
```

```
                OUT     (+FE),A         Perform the OUT operation;
                                        leaving the border unchanged.
                LD      B,H             Reset the B register.
                LD      C,A             Save the A register.
                BIT     4,A             Jump if at the half-cycle
                JR      NZ,03F2,BE-AGAIN point.
```

After a full cycle the DE register pair is tested.

```
                LD      A,D             Jump forward if the last
                OR      E               complete pass has been
                JR      Z,03D6,BE-END   made already.
                LD      A,C             Fetch the saved value.
                LD      C,L             Reset the C register.
                DEC     DE              Decrease the pass counter.
                JP      (IX)            Jump back to the required
                                        starting location of the loop.
```

The parameters for the second half-cycle are set up.

```
03F2    BE-AGAIN LD     C,L             Reset the C register.
                INC     C               Add '16' T states as this path
                                        is shorter.
                JP      (IX)            Jump back.
```

Upon completion of the 'beep' the maskable interrupt has to be enabled.

```
03F6    BE-END  EI                      Enable interrupt.
                RET                     Finally return.
```

THE 'BEEP' COMMAND ROUTINE

The subroutine is entered with two numbers on the calculator stack. The topmost number represents the 'pitch' of the note and the number underneath it represents the 'duration'.

```
03F8    BEEP    RST     0028,FP-CALC    The floating-point calculator is
                                        used to manipulate the two values - t & P.
                DEFB    +31,duplicate   t,P,P
                DEFB    +27,int         t,P,P
                DEFB    +C0,st-mem-0    t,P,i (mem-0 holds i)
                DEFB    +03,subtract    t,P (where p is the fractional
                                        part of P)
                DEFB    +34,stk-data    Stack the decimal value 'K'.
                DEFB    +EC,exponent+7C 0.0577622606 (which is a
                DEFB    +6C,+98,+1F,+F5 little below 12*(2^0.5)-1)
                DEFB    +04,multiply    t,pK
                DEFB    +A1,stk-one     t,pK,1
                DEFB    +0F,addition    t,pK+1
                DEFB    +38,end-calc
```

Now perform several tests on I, the integer part of the 'pitch'.

```
                LD      HL,+5C92        This is 'mem-0-1st (MEMBOT).
                LD      A,(HL)          Fetch the exponent of i.
                AND     A               Give an error if i is not in the
                JR      NZ,046C,REPORT-B integral (short) form.
                INC     HL              Copy the sign byte to the
                LD      C,(HL)          C register.
                INC     HL              Copy the low-byte to the
                LD      A,B             register.
                RLA                     Again give report B if i does not
                SBC     A,A             satisfy the test:
                CP      C               -128<=i<=+127
                JR      NZ,046C,REPORT-B
                INC     HL
                CP      (HL)
```

```
                JR      NZ,046C,REPORT-B
                LD      A,B             Fetch the low-byte and test
                                        it further.
                ADD     A,+3C
                JP      P,0425,BE-I-OK  Accept -60<=i<=67.
                JP      PO,046C,REPORT-B Reject -128 to -61.
```

Note: The range +70 to +127 will be rejected later on.

The correct frequency for the 'pitch' i can now be found.

```
0425    BE-I-OK     LD      B,+FA           Start '6' octaves below middle C.
0427    BE-OCTAVE   INC     B               Repeatedly reduce i in order to
                    SUB     +0C             find the correct octave.
                    JR      NC,0427,BE-OCTAVE
                    ADD     A,+0C           Ass back the last subtraction.
                    PUSH    BC              Save the octave number.
                    LD      HL,+046E        The base address of the 'semi-
                                            tone table'.
                    CALL    3406,LOC-MEM    Consider the table and pass the
                    CALL    33B4,STACK-NUM  'A th.' value to the calculator
                                            stack. (Call it C.)
```

Now the fractional part of the 'pitch' can be taken into consideration.

```
                RST     0028,FP-CALC    t, pK+1, C
                DEFB    +04,multiply    t, C(pK+1)
                DEFB    +38,end-calc
```

The final frequency f is found by modifying the 'last value' according to the octave number.

```
                POP     AF              Fetch the octave number.
                ADD     A,(HL)          Multiply the 'last value' by
                LD      (HL),A          '2 to the power of the octave
                                        number'.
                RST     0028,FP-CALC    t, f
                DEFB    +C0,st-mem-0    The frequency is put aside for
                DEFB    +02,delete      the moment in mem-0.
```

Attention is now turned to the 'duration'.

```
                DEFB    +31,duplicate   t, t
                DEFB    +38,end-calc
                CALL    1E94,FIND-INT1  The value 'INT t' must be in
                CP      +0B             the range +00 to +0A.
                JR      NC,046C,REPORT-B
```

The number of complete cycles in the 'beep' is given by 'f*t' so this value is now found.

```
                RST     0028,FP-CALC    t
                DEFB    +E0,get-mem-0   t, f
                DEFB    +04,multiply    f*t
```

The result is left on the calculator stack whilst the length of the 'timing loop' required for the 'beep' is computed;

```
                DEFB    +E0,get-mem-0   f*t
                DEFB    +34,stk-data    The value '3.5 * 10^6/8'
                DEFB    +80,four bytes  is formed on the top of
                DEFB    +43,exponent +93 the calculator stack.
                DEFB    +55,+9F,+80,(+00) f*t, f, 437,500 (dec.)
                DEFB    +01,exchange    f*t, 437,500, f
                DEFB    +05,division    f*t, 437,500/f
                DEFB    +34,stk-data
                DEFB    +35,exponent +85
                DEFB    +71,(+00,+00,+00) f*t, 437,500/f, 30.125 (dec.)
                DEFB    +03,subtract    f*t, 437,500/f - 30.125
                DEFB    +38,end-calc
```

Note: The value '437,500/f' gives the 'half-cycle' length of the note and reducing it by '30.125' allows for '120.5' T states in which to actually produce the note and adjust the counters etc.
The values can now be transferred to the required registers.

```
                CALL    1E99,FIND-INT2  The 'timing loop' value is
                                        compressed into the BC
                PUSH    BC              register pair; and saved.
```

Note: If the timing loop value is too large then an error will occur (returning via ERROR-1); thereby excluding 'pitch' values of '+70 to +127'.

```
                CALL    1E99,FIND-INT2  The 'f*t' value is compressed
                                        into the BC register pair.
                POP     HL              Move the 'timing loop' value to
                                        the HL register pair.
                LD      D,B             Move the 'f*t' value to the
                LD      E,C             DE register pair.
```

However before making the 'beep' test the value 'f*t'.

```
                LD      A,D             Return if 'f*t' has given the
                OR      E               result of 'no cycles'
                RET     Z               required.
                DEC     DE              Decrease the cycle number and
                JP      03B5,BEEPER     jump to the BEEPER subroutine
                                        (making, at least, one pass).
```

Report B - integer out of range

```
046C  REPORT-B  RST     0008,ERROR-1    Call the error handling
                DEFB    +0A             routine.
```

THE 'SEMI-TONE' TABLE

This table holds the frequencies of the twelve semi-tones in an octave.

```
                                        frequency hz.   note
046E    DEFB    +89,+02,+D0,+12,+86     261.63          C
        DEFB    +89,+0A,+97,+60,+75     277.18          C#
        DEFB    +89,+12,+D5,+17,+1F     293.66          D
        DEFB    +89,+1B,+90,+41,+02     311.12          D#
        DEFB    +89,+24,+D0,+53,+CA     329.63          E
        DEFB    +89,+2E,+9D,+36,+B1     349.23          F
        DEFB    +89,+38,+FF,+49,+3E     369.99          F#
        DEFB    +89,+43,+FF,+6A,+73     392             G
        DEFB    +89,+4F,+A7,+00,+54     415.30          G#
        DEFB    +89,+5C,+00,+00,+00     440             A
        DEFB    +89,+69,+14,+F6,+24     466.16          A#
        DEFB    +89,+76,+F1,+10,+05     493.88          B
```

THE 'PROGRAM NAME' SUBROUTINE (ZX81)
The following subroutine applies to the ZX81 and was not removed when the program was rewritten for the SPECTRUM.

```
04AA    DEFB    +CD,+FB,+24,+3A
        DEFB    +3B,+5C,+87,+FA
        DEFB    +8A,+1C,+E1,+D0
        DEFB    +E5,+CD,+F1,+2B
        DEFB    +62,+6B,+0D,+F8
        DEFB    +09,+CB,+FE,+C9
```

THE CASSETTE HANDLING ROUTINES

The 16K monitor program has an extensive set of routines for handling the cassette interface. In effect these routines form the SAVE. LOAD, VERIFY & MERGE command routines.
The entry point to the routines is at SAVE-ETC (0605). However before this point are the subroutines concerned with the actual SAVEing and LOADing (or VERIFYing) of bytes.
In all cases the bytes to be handled by these subroutines are described by the DE register pair holding the 'length' of the block, the IX register pair holding the 'base address' and the A register holding +00 for a header block, or +FF for a program/data block.

THE 'SA-BYTES' SUBROUTINE

This subroutine is called to SAVE the header information (from 09BA) and later the actual program/data block (from 099E).

04C2	SA-BYTES	LD	HL,+053F	Pre-load the machine stack with
		PUSH	HL	the address - SA/LD-RET.
		LD	HL,+1F80	This constant will give a leader of about 5 secs. for a 'header'.
		BIT	7,A	Jump forward if SAVEing a
		JR	Z,04D0,SA-FLAG	header.
		LD	HL,+0C98	This constant will give a leader of about 2 secs. for a program/ data block.
04D0	SA-FLAG	EX	AF,A'F'	The flag is saved.
		INC	DE	The 'length' is incremented
		DEC	IX	and the 'base address' reduced to allow for the flag.
		DI		The maskable interrupt is disabled during the SAVE.
		LD	A,+02	Signal 'MIC on' and border to be RED.
		LD	B,A	Give a value to B.

A loop is now entered to create the pulses of the leader. Both the 'MIC on' and the 'MIC off' pulses are 2,168 T states in length. The colour of the border changes from RED to CYAN with each 'edge'.

Note: An 'edge' will be a transition either from 'on' to 'off', or from 'off' to 'on'.

04D8	SA-LEADER	DJNZ	04D8,SA-LEADER	The main timing period.
		OUT	(+FE),A	MIC on/off, border RED/CYAN,
		XOR	+0F	on each pass.
		LD	B,+A4	The main timing constant.
		DEC	L	Decrease the low counter.
		JR	NZ,04D8,SA-LEADER	Jump back for another pulse.
		DEC	B	Allow for the longer path (-reduce by 13 T states).
		DEC	H	Decrease the high counter.
		JP	P,04D8,SA-LEADER	Jump back for another pulse until completion of the leader.

A sync pulse is now sent.

		LD	B,+2F	
04EA	SA-SYNC-1	DJNZ	04EA,SA-SYNC-1	MIC off for 667 T states from 'OUT to OUT'.
		OUT	(+FE),A	MIC on and RED.
		LD	A,+0D	Signal 'MIC off & CYAN'.
		LD	B,+37	MIC on for 735 T States from
04F2	SA-SYNC-2	DJNZ	04F2,SA-SYNC-2	'OUT to OUT'.
		OUT	(+FE),A	Now MIC off & border CYAN.

The header v. program/data flag will be the first byte to be SAVEd.

```
                LD      BC,+3B0E        +3B is a timing constant; +0E
                                        signals 'MIC off & YELLOW'.
                EX      AF,A'F'         Fetch the flag and pass it to the
                LD      L,A             L register for 'sending'.
                JP      0507,SA-START   Jump forward into the SAVEing
                                        loop.
```

The byte SAVEing loop is now entered. The first byte to be SAVEd is the flag; this is followed by the actual data byte and the final byte sent is the parity byte that is built up by considering the values of all the earlier bytes.

```
04FE    SA-LOOP     LD      A,D             The 'length' counter is tested
                    OR      E               and the jump taken when it
                    JR      Z,050E,SA-PARITY has reached zero.
                    LD      L,(IX+00)       Fetch the next byte that is to
                                            be SAVEd.
0505    SA-LOOP-P   LD      A,H             Fetch the current 'parity'.
                    XOR     L               Include the present byte.
0507    SA-START    LD      H,A             Restore the 'parity'. Note that
                                            on entry here the 'flag' value
                                            initialises 'parity'.
                    LD      A,+01           Signal 'MIC on & BLUE'.
                    SCF                     Set the carry flag. This will act
                                            as a 'marker' for the 8 bits of a
                                            byte.
                    JP      0525,SA-8-BITS  Jump forward.
```

When it is time to send the 'parity' byte then it is transferred to the L register for SAVEing.

```
050E    SA-PARITY   LD      L,H             Get final 'parity' value.
                    JR      0505,SA-LOOP-P  Jump back.
```

The following inner loop produces the actual pulses. The loop is entered at SA-BIT-1 with the type of the bit to be SAVEd indicated by the carry flag. Two passes of the loop are made for each bit thereby making an 'off pulse' and an 'on pulse'. The pulses for a reset bit are shorter by 855 T states.

```
0511    SA-BIT-2    LD      A,C             Come here on the second pass
                                            and fetch 'MIC off & YELLOW'.
                    BIT     7,B             Set the zero flag to show
                                            'second pass'.
0514    SA-BIT-1    DJNZ    0514,SA-BIT-1   The main timing loop; always
                                            801 T states on a 2nd. pass.
                    JR      NC,051C,SA-OUT  Jump, taking the shorter path, if
                                            SAVEing a '0'.
                    LD      B,+42           However if SAVEing a '1' then
051A    SA-SET      DJNZ    051A,SA-SET     add 855 T states.
051C    SA-OUT      OUT     (+FE),A         On the 1st. pass 'MIC on &
                                            BLUE' and on the 2nd. pass
                                            'MIC off & YELLOW'.
                    LD      B,+3E           Set the timing constant for
                                            the second pass.
                    JR      NZ,0511,SA-BIT-2 Jump back at the end of the
                    DEC     B               first pass; otherwise reclaim
                                            13 T states.
                    XOR     A               Clear the carry flag and set
                    INC     A               A to hold +01 (MIC on & BLUE}
                                            before continuing into the
                                            '8 bit loop'.
```

The '8 bit loop' is entered initially with the whole byte in the L register and the carry flag set. However it is re-entered after each bit has been SAVEd until the point is reached when the 'marker' passes to the carry flag leaving the L register empty.

```
0525    SA-8-BITS   RL      L               Move bit 7 to the carry and the
                                            'marker' leftwards.
```

```
                    JP      NZ,0514,SA-BIT-1    SAVE the bit unless finished
                                                with the byte.
                    DEC     DE                  Decrease the 'counter'.
                    INC     IX                  Advance the 'base address'.
                    LD      B,+31               Set the timing constant for the
                                                first bit of the next byte.
                    LD      A,+7F               Return (to SA/LD-RET) if the
                    IN      A,(+FE)             BREAK key is being pressed.
                    RRA
                    RET     NC
                    LD      A,D                 Otherwise test the 'counter
                    INC     A                   and jump back even if it has
                    JP      NZ,04FE,SA-LOOP     reached zero (so as to send the
                                                'parity' byte).
                    LD      B,+3B               Exit when the 'counter
053C  SA-DELAY      DJNZ    053C,SA-DELAY       reaches +FFFF. But first
                    RET                         give a short delay.
```

Note: A reset bit will give a 'MIC off' pulse of 855 T states followed by a 'MIC on' pulse of 855 T states. Whereas a Set bit will give pulses of exactly twice as long. Note also that there are no gaps either between the sync pulse and the first bit of the flag, or between bytes.

THE 'SA/LD-RET' SUBROUTINE

This subroutine is common to both SAVEing and LOADing.
The border is set to its original colour and the BREAK key tested for a last time.

```
053F  SA/LD-RET     PUSH    AF                  Save the carry flag. (It is reset
                                                after a LOADing error.)
                    LD      A,(BORDCR)          Fetch the original border colour
                    AND     +38                 from its system variable.
                    RRCA                        Move the border colour
                    RRCA                        to bits 2, l & 0.
                    RRCA
                    OUT     (+FE),A             Set the border to its original
                                                colour.
                    LD      A.+7F               Read the BREAK key for a
                    IN      A,(+FE)             last time.
                    RRA
                    EI                          Enable the maskable interrupt.
                    JR      C,0554,SA/LD-END    Jump unless a break is to be
                                                made.
```

Report D - BREAK-CONT repeats

```
0552  REPORT-D      RST     0008,ERROR-l        Call the error handling
                    DEFB    +0C                 routine.
```

Continue here.

```
0554  SA/LD-END     POP     AF                  Retrieve the carry flag.
                    RET                         Return to the calling routine.
```

THE 'LD-BYTES' SUBROUTINE

This subroutine is called to LOAD the header information (from 07BE) and later LOAD, or VERIFY, an actual block of data (from 0802).

```
0556  LD-BYTES      INC     D                   This resets the zero flag. (D
                                                cannot hold +FF.)
                    EX      AF,A'F'             The A register holds +00 for a
                                                header and +FF for a block of
                                                data.
                                                The carry flag is reset for
                                                VERIFYing and set for
                                                LOADing.
                    DEC     D                   Restore D to its original value.
```

```
                DI                          The maskable interrupt is now
                                            disabled.
                LD      A,+0F               The border is made WHITE.
                OUT     (+FE),A
                LD      HL,+053F            Preload the machine stack
                PUSH    HL                  with the address - SA/LD-RET.
                IN      A,(+FE)             Make an initial read of port '254'
                RRA                         Rotate the byte obtained but
                AND     +20                 keep only the EAR bit,
                OR      +02                 Signal 'RED' border.
                LD      C,A                 Store the value in the C register. -
                                            (+22 for 'off' and +02 for 'on'
                                            - the present EAR state.)
                CP      A                   Set the zero flag.
```

The first stage of reading a tape involves showing that a pulsing signal actually exist (i.e. 'On/off' or 'off/on' edges.)

```
056B    LD-BREAK    RET     NZ              Return if the BREAK key is
                                            being pressed.
056C    LD-START    CALL    05E7,LD-EDGE-1  Return with the carry flag reset
                    JR      NC,056B,LD-BREAK if there is no 'edge' within
                                            approx. 14,000 T states. But if
                                            an 'edge' is found the border
                                            will go CYAN.
```

The next stage involves waiting a while and then showing that the signal is still pulsing.

```
                    LD      HL,+0415        The length of this waiting
0574    LD-WAIT     DJNZ    0574,LD-WAIT    period will be almost one
                    DEC     HL              second in duration.
                    LD      A,H
                    OR      L
                    JR      NZ,0574,LD-WAIT
                    CALL    05E3,LD-EDGE-2  Continue only if two edges are
                    JR      NC,056B,LD-BREAK found within the allowed time
                                            period.
```

Now accept only a 'leader signal'.

```
0580    LD-LEADER   LD      B,+9C           The timing constant,
                    CALL    05E3,LD-EDGE-2  Continue only if two edges are
                    JR      NC,056B,LD-BREAK found within the allowed time
                                            period.
                    LD      A,+C6           However the edges must have
                    CP      B               been found within about
                    JR      NC,056C,LD-START 3,000 T states of each other
                    INC     H               Count the pair of edges in the H
                    JR      NZ,0580,LD-LEADER register until '256' pairs have
                                            been found.
```

After the leader come the 'off' and 'on' part's of the sync pulse.

```
058F    LD-SYNC     LD      B,+9C           The timing constant.
                    CALL    05E7,LD-EDGE-1  Every edge is considered until
                    JR      NC,056B,LD-BREAK two edges are found close
                    LD      A,B             together - these will be the
                    CP      +D4             start and finishing edges of
                    JR      NC,058F,LD-SYNC the 'off' sync pulse.
                    CALL    05E7,LD-EDGE-1  The finishing edge of the
                    RET     NC              'on' pulse must exist.
                                            (Return carry flag reset.)
```

The bytes of the header or the program/data block can now be LOADed or VERIFied. But the first byte is the type flag.

```
                    LD      A,C             The border colours from now
                    XOR     +03             on will be BLUE & YELLOW.
```

```
                    LD      C,A
                    LD      H,+00           Initialise the 'parity matching'
                                            byte to zero.
                    LD      B,+B0           Set the timing constant for the
                                            flag byte.
                    JR      05C8,LD-MARKER  Jump forward into the byte
                                            LOADING loop.
```

The byte LOADing loop is used to fetch the bytes one at a time. The flag byte is first. This is followed by the data bytes and the last byte is the 'parity' byte.

```
05A9    LD-LOOP     EX      AF,A'F'         Fetch the flags.
                    JR      NZ,05B3,LD-FLAG Jump forward only when
                                            handling the first byte.
                    JR      NC,05BD,LD-VERIFY Jump forward if VERIFYing a
                                            tape.
                    LD      (IX+00),L       Make the actual LOAD when
                                            required.
                    JR      05C2,LD-NEXT    Jump forward to LOAD the
                                            next byte.
05B3    LD-FLAG     RL      C               Keep the carry flag in a safe
                                            place temporarily.
                    XOR     L               Return now if the type flag does
                    RET     NZ              not match the first byte on the
                                            tape. (Carry flag reset.)
                    LD      A,C             Restore the carry flag now.
                    RRA
                    LD      C,A
                    INC     DE              Increase the counter to
                    JR      05CA,LD-DEC     compensate for its 'decrease'
                                            after the jump.
```

If a data block is being verified then the freshly loaded byte is tested against the original byte.

```
05BD    LD-VERIFY   LD      A,(IX+00)       Fetch the original byte.
                    XOR     L               Match it against the new byte.
                    RET     NZ              Return if 'no match'. (Carry
                                            flag reset.)
```

A new byte can now be collected from the tape.

```
05C2    LD-NEXT     INC     IX              Increase the 'destination'.
05C4    LD-DEC      DEC     DE              Decrease the 'counter'.
                    EX      AF,A'F'         Save the flags.
                    LD      B,+B2           Set the timing constant.
05C8    LD-MARKER   LD      L,+01           Clear the 'object' register apart
                                            from a 'marker' bit.
```

The 'LD-8-BITS' loop is used to build up a byte in the L register.

```
05CA    LD-8-BITS   CALL    05E3,LD-EDGE-2  Find the length of the 'off'
                                            and 'on' pulses of the next bit.
                    RET     NC              Return if the time period is
                                            exceeded. (Carry flag reset.)
                    LD      A,+C5           Compare the length against
                                            approx. 2,400 T states; resetting
                    CP      B               the carry flag for a '0' and
                                            setting it fore '1'.
                    RL      L               Include the new bit in the L
                                            register.
                    LD      B,+B0           Set the timing constant for the
                                            next bit.
                    JP      NC,05CA,LD-8-BITS Jump back whilst there are still
                                            bits to be fetched.
```

The 'parity matching' byte has to be updated with each new byte.

```
                LD      A,H             Fetch the 'parity matching'
                XOR     L               byte and include the new byte.
                LD      H,A             Save it once again.
```

Passes round the loop are made until the 'counter' reaches zero. At that point the 'parity matching' byte should be holding zero.

```
                LD      A,D             Make a further pass if the DE
                OR      E               register pair does not hold
                JR      NZ,05A9,LD-LOOP zero.
                LD      A,H             Fetch the 'parity matching'
                                        byte.
                CP      +01             Return with the carry flat set
                RET                     if the value is zero.
                                        (Carry flag reset if in error.)
```

THE 'LD-EDGE-2' AND 'LD-EDGE-1' SUBROUTINES

These two subroutines form the most important part of the LOAD/VERIFY operation.

The subroutines are entered with a timing constant in the B register, and the previous border colour and 'edge-type' in the C register.

The subroutines return with the carry flag set if the required number of 'edges' have been found in the time allowed; and the change to the value in the B register shows just how long it took to find the 'edge(s)'.

The carry flag will be reset if there is an error. The zero flag then signals 'BREAK pressed' by being reset, or 'time-up' by being set.

The entry point LD-EDGE-2 is used when the length of a complete pulse is required and LD-EDGE-1 is used to find the time before the next 'edge'.

```
05E3    LD-EDGE-2   CALL    05E7,LD-EDGE-1  In effect call LD-EDGE-1 twice;
                    RET     NC              returning in between if there
                                            is an error.
05E7    LD-EDGE-1   LD      A,+16           Wait 358 T states before
05E9    LD-DELAY    DEC     A               entering the sampling loop.
                    JR      NZ,05E9,LD-DELAY
                    AND     A
```

The sampling loop is now entered. The value in the B register is incremented for each pass; 'time-up' is given when B reaches zero.

```
05ED    LD-SAMPLE   INC     B               Count each pass.
                    RET     Z               Return carry reset & zero set if
                                            'time-up'.
                    LD      A,+7F           Read from port +7FFE.
                    IN      A,(+FE)         i.e. BREAK & EAR.
                    RRA                     Shift the byte.
                    RET     NC              Return carry reset & zero reset
                                            if BREAK was pressed.
                    XOR     C               Now test the byte against the
                    AND     +20             'last edge-type'; jump back
                    JR      Z,05ED,LD-SAMPLE unless it has changed.
```

A new 'edge' has been found within the time period allowed for the search. So change the border colour and set the carry flag.

```
                    LD      A,C             Change the 'last edge-type'
                    CPL                     and border colour.
                    LD      C,A
                    AND     +07             Keep only the border colour.
                    OR      +08             Signal 'MIC off'.
                    OUT     (+FE),A         Change the border colour (RED/
                                            CYAN or BLUE/YELLOW).
                    SCF                     Signal the successful search
                    RET                     before returning.
```

Note: The LD-EDGE-1 subroutine takes 465 T states, plus an additional 58 T states for each unsuccessful pass around the sampling loop.

For example, therefore, when awaiting the sync pulse (see LD-SYNC at 058F) allowance is made for ten additional passes through the sampling loop. The search is thereby for the next edge to be found within, roughly, 1,100 T states (465 + 10 * 58 + overhead). This will prove successful for the sync 'off' pulse that comes after the long 'leader pulses'.

THE 'SAVE, LOAD, VERIFY & MERGE' COMMAND ROUTINES

The entry point SAVE-ETC is used for all four commands. The value held in T-ADDR however distinguishes between the four commands. The first part of the following routine is concerned with the construction of the 'header information' in the work space.

```
0605  SAVE-ETC   POP    AF              Drop the address - SCAN-LOOP.
                 LD     A,(T-ADDR-lo)   Reduce T-ADDR-lo by +E0;
                 SUB    +E0             giving +00 for SAVE, +01 for
                 LD     (T-ADDR-lo),A   LOAD, +02 for VERIFY and
                                        +03 for MERGE.
                 CALL   1C8C,EXPT-EXP   Pass the parameters of the
                                        'name' to the calculator stack.
                 CALL   2530,SYNTAX-Z   Jump forward if checking
                 JR     Z,0652,SA-DATA  syntax.
                 LD     BC,+0011        Allow seventeen locations
                 LD     A,(T-ADDR-lo)   for the header of a SAVE but
                 AND    A               thirty four for the other
                 JR     Z,0621,SA-SPACE commands.
                 LD     C,+22
0621  SA-SPACE   RST    0030,BC-SPACES  The required amount of space is
                                        made in the work space.
                 PUSH   DE              Copy the start address to the
                 POP    IX              IX register pair.
                 LD     B,+0B           A program name can have
                 LD     A,+20           up to ten characters but
0629  SA-BLANK   LD     (DE),A          first enter eleven space
                 INC    DE              characters into the prepared
                 DJNZ   0629,SA-BLANK   area.
                 LD     (IX+01),+FF     A null name is +FF only.
                 CALL   2BF1,STK-FETCH  The parameters of the name
                                        are fetched and its length is
                                        tested.
                 LD     HL,+FFF6        This is '-10'.
                 DEC    BC              In effect jump forward if the
                 ADD    HL,BC           length of the name is not
                 INC    BC              too long. (i.e. No more than
                 JR     NC,064B,SA-NAME ten characters.)
                 LD     A,(T-ADDR-lo)   But allow for the LOADing,
                 AND    A               VERIFYing and MERGEing of
                 JR     NZ,0644,SA-NULL programs with 'null' names or
                                        extra long names.
```

Report F - Invalid file name

```
0642  REPORT-F   RST    0008,ERROR-1    Call the error handling
                 DEFB   +0E             routine.
```

Continue to handle the name of the program.

```
0644  SA-NULL    LD     A,B             Jump forward if the name
                 OR     C               has a 'null' length.
                 JR     Z,0652,SA-DATA
                 LD     BC,+000A        But truncate longer names.
```

The name is now transferred to the work space (second location onwards).

```
064B  SA-NAME    PUSH   IX              Copy the start address to the
                 POP    HL              HL register pair.
                 INC    HL              Step to the second location.
                 EX     DE,HL           Switch the pointers over and
                 LDIR                   copy the name.
```

The many different parameters, if any, that follow the command are now considered. Start by handling 'xxx "name" DATA'.

```
0652  SA-DATA     RST   0018,GET-CHAR      Is the present code the
                  CP    +E4                token 'DATA'?
                  JR    NZ,06A0,SA-SCR$    Jump if not.
                  LD    A,(T-ADDR-lo)      However it is not possible
                  CP    +03                to have 'MERGE name DATA'.
                  JP    Z,1C8A,REPORT-C
                  RST   0020,NEXT-CHAR     Advance CH-ADD.
                  CALL  28B2,LOOK-VARS     Look in the variables area for
                                           the array.
                  SET   7,C                Set bit 7 of the array's name.
                  JR    NC,0672,SA-V-OLD   Jump if handling an existing
                                           array.
                  LD    HL,+0000           Signal 'using a new array'.
                  LD    A,(T-ADDR-lo)      Consider the value in T-ADDR
                  DEC   A                  and give an error if trying to
                  JR    Z,0685,SA-V-NEW    SAVE or VERIFY a new array.
```

Report 2 - Variable not found

```
0670  REPORT-2    RST   0008,ERROR-1       Call the error handling
                  DEFB  +01                routine.
```

Continue with the handling of an existing array.

```
0672  SA-V-OLD    JP    NZ,1C8A,REPORT-C   Note: This fails to exclude
                                           simple strings.
                  CALL  2530,SYNTAX-Z      Jump forward if checking
                  JR    Z,0692,SA-DATA-1   syntax.
                  INC   HL                 Point to the 'low length' of the
                                           variable.
                  LD    A,(HL)             The low length byte goes into
                  LD    (IX+0B),A          the work space; followed by
                  INC   HL                 the high length byte.
                  LD    A,(HL)
                  LD    (IX+0C),A
                  INC   HL                 Step past the length bytes.
```

The next part is common to both 'old' and 'new' arrays. **Note:** Syntax path error.

```
0685  SA-V-NEW    LD    (IX+0E),C          Copy the array's name.
                  LD    A,+01              Assume an array of numbers.
                  BIT   6,C                Jump if it is so.
                  JR    Z,068F,SA-V-TYPE
                  INC   A                  It is an array of characters.
068F  SA-V-TYPE   LD    (IX+00),A          Save the 'type' in the first
                                           location of the header area.
```

The last part of the statement is examined before joining the other pathways.

```
0692  SA-DATA-1   EX    DE,HL              Save the pointer in DE.
                  RST   0020,NEXT-CHAR     Is the next character
                  CP    +29                a ')' ?
                  JR    NZ,0672,SA-V-OLD   Give report C if it is not.
                  RST   0020,NEXT-CHAR     Advance CH-ADD.
                  CALL  1BEE,CHECK-END     Move on to the next statement
                                           if checking syntax.
                  EX    DE,HL              Return the pointer to the HL
                  JP    075A,SA-ALL        register pair before jumping
                                           forward. (The pointer indicates
                                           the start of an existing array's
                                           contents.)
```

Now consider 'SCREEN$'.

```
06A0  SA-SCR$     CP    +AA                Is the present code the
                                           token SCREEN$'.
```

```
                    JR      NZ,06C3,SA-CODE     Jump if not.
                    LD      A,(T-ADDR-lo)       However it is not possible to
                    CP      +03                 have 'MERGE name SCREEN$'.
                    JP      Z,1C8A,REPORT-C
                    RST     0020,NEXT-CHAR      Advance CH-ADD.
                    CALL    1BEE,CHECK-END      Move on to the next statement
                                                if checking syntax.
                    LD      (IX+0B),+00         The display area and the
                    LD      (IX+0C),+1B         attribute area occupy +1800
                                                locations and these locations
                    LD      HL,+4000            start at +4000; these details
                    LD      (IX+0D),L           are passed to the header area
                    LD      (IX+0E),H           in the work space.
                    JR      0710,SA-TYPE-3      Jump forward.
```

Now consider 'CODE'.

```
06C3    SA-CODE     CP      +AF                 Is the present code the token
                                                'CODE'?
                    JR      NZ,0716,SA-LINE     Jump if not.
                    LD      A,(T-ADDR-lo)       However it is not possible to
                    CP      +03                 have 'MERGE name CODE'.
                    JP      Z,1C8A,REPORT-C
                    RST     0020,NEXT-CHAR      Advance CH-ADD.
                    CALL    2048,PR-ST-END      Jump forward if the statement
                    JR      NZ,06E1,SA-CODE-1   has not finished.
                    LD      A,(T-ADDR-lo)       However it is not possible to
                    AND     A                   have 'SAVE name CODE' by
                    JP      Z,1C8A,REPORT-C     itself.
                    CALL    1CE6,USE-ZERO       Put a zero on the calculator
                                                stack - for the 'start'.
                    JR      06F0,SA-CODE-2      Jump forward.
```

Look for a 'starting address'.

```
06E1    SA-CODE-1   CALL    1C82,EXPT-1NUM      Fetch the first number.
                    RST     0018,GET-CHAR       Is the present character a ','
                    CP      +2C                 or not?
                    JR      Z,06F5,SA-CODE-3    Jump if it is - the number was
                                                a 'starting address'.
                    LD      A,(T-ADDR-lo)       However refuse 'SAVE name
                    AND     A                   CODE' that does not have a
                    JP      Z,1C8A,REPORT-C     'start' and a 'length'.
06F0    SA-CODE-2   CALL    1CE6,USE-ZERO       Put a zero on the calculator
                                                stack - for the 'length'.
                    JR      06F9,SA-CODE-4      Jump forward.
```

Fetch the 'length' as it was specified.

```
06F5    SA-CODE-3   RST     0020,NEXT-CHAR      Advance CH-ADD.
                    CALL    1C82,EXPT-1NUM      Fetch the 'length'.
```

The parameters are now stored in the header area of the work space.

```
06F9    SA-CODE-4   CALL    1BEE,CHECK-END      But move on to the next state-
                                                ment now if checking syntax.
                    CALL    1E99,FIND-INT2      Compress the 'length' into
                    LD      (IX+0B),C           the BC register pair and
                    LD      (IX+0C),B           store it.
                    CALL    1E99,FIND-INT2      Compress the 'starting address'
                    LD      (IX+0D),C           into the BC register pair
                    LD      (IX+0E),B           and store it.
                    LD      H,B                 Transfer the 'pointer' to the
                    LD      L,C                 HL register pair as usual.
```

'SCREEN$' and 'CODE' are both of type 3.

```
0710    SA-TYPE-3   LD      (IX+00),+03         Enter the 'type' number.
```

```
                    JR          075A,SA-ALL         Rejoin the other pathways.
```

Now consider 'LINE'; and 'no further parameters'.

```
0716    SA-LINE     CP          +CA                 Is the present code the token
                                                    'LINE'?
                    JR          Z,0723,SA-LINE-1    Jump if it is.
                    CALL        1BEE,CHECK-END      Move on to the next statement
                                                    if checking syntax.
                    LD          (IX+0E),+80         When there are no further
                                                    parameters an +80 is entered.
                    JR          073A,SA-TYPE-0      Jump forward.
```

Fetch the 'line number' that must follow 'LINE'.

```
0723    SA-LINE-1   LD          A,(T-ADDR-lo)       However only allow 'SAVE
                    AND         A                   name LINE number'.
                    JP          NZ,1C8A,REPORT-C
                    RST         0020,NEXT-Char      Advance CH-ADD.
                    CALL        1C82,EXPT-1NUM      Pass the number to the
                                                    calculator stack.
                    CALL        1BEE,CHECK-END      Move on to the next statement
                                                    if checking syntax.
                    CALL        1E99,FIND-INT2      Compress the 'line number'
                    LD          (IX+0D),C           into the BC register pair
                    LD          (IX+0E),B           and store it.
```

'LINE' and 'no further parameters' are both of type 0.

```
073A    SA-TYPE-0   LD          (IX+00),+00         Enter the 'type' number.
```

The parameters that describe the program, and its variables, are found and stored in the header area of the work space.

```
                    LD          HL,(E-LINE)         The pointer to the end of the
                                                    variables area.
                    LD          DE,(PROG)           The pointer to the start of the
                                                    BASIC program.
                    SCF                             Now perform the subtraction
                    SBC         HL,DE               to find the length of the
                    LD          (IX+0B),L           'program + variables'; store
                    LD          (IX+0C),H           the result.
                    LD          HL,(VARS)           Repeat the operation but this
                    SBC         HL,DE               time storing the length of the
                    LD          (IX+0F),L           'program' only.
                    LD          (IX+10),H
                    EX          DE,HL               Transfer the 'pointer' to the
                                                    HL register pair as usual.
```

In all cases the header information has now been prepared.

The location 'IX+00' holds the type number.
Locations 'IX+01 to IX+0A' holds the name (+FF in 'IX+01' if null).
Locations 'IX+0B & IX+0C' hold the number of bytes that are to be found in the 'data block'.
Locations 'IX+0D to IX+10' hold a variety of parameters whose exact interpretation depends on the 'type'.

The routine continues with the first task being to separate SAVE from LOAD, VERIFY and MERGE.

```
075A    SA-ALL      LD          A,(T-ADDR-lo)       Jump forward when handling
                    AND         A                   a SAVE command.
                    JP          Z,0970,SA-CONTRL
```

In the case of a LOAD, VERIFY or MERGE command the first seventeen bytes of the 'header area' in the work space hold the prepared information, as detailed above; and it is now time to fetch a 'header' from the tape.

```
                    PUSH        HL                  Save the 'destination' pointer.
```

```
                LD      BC,+0011        Form in the IX register pair
                ADD     IX,BC           the base address of the 'second
                                        header area'.
```

Now enter a loop; leaving it only when a 'header' has been LOADed.

```
0767    LD-LOOK-H PUSH  IX              Make a copy of the base address.
                LD      DE,+0011        LOAD seventeen bytes.
                XOR     A               Signal 'header'.
                SCF                     Signal 'LOAD'.
                CALL    0556,LD-BYTES   Now look for a header.
                POP     IX              Retrieve the base address.
                JR      NC,0767,LD-LOOK-H Go round the loop until
                                        successful.
```

The new 'header' is now displayed on the screen but the routine will only proceed if the 'new' header matches the 'old' header.

```
                LD      A,+FE           Ensure that channel 'S'
                CALL    1601,CHAN-OPEN  is open.
                LD      (SCR-CT),+03    Set the scroll counter.
                LD      C,+80           Signal 'names do not match'.
                LD      A,(IX+00)       Compare the 'new' type
                CP      (IX-11)         against the 'old' type.
                JR      NZ,078A,LD-TYPE Jump if the 'types' do not
                                        match.
                LD      C,+F6           But if they do; signal 'ten
                                        characters are to match'.
078A    LD-TYPE CP      +04             Clearly the 'header' is
                JR      NC,0767,LD-LOOK-H nonsense if 'type 4 or more'.
```

The appropriate message - 'Program:', 'Number array:', 'Character array:' or 'Bytes:' is printed.

```
                LD      DE,+09C0        The base address of the message
                                        block.
                PUSH    BC              Save the C register whilst
                CALL    0C0A,PO-MSG     the appropriate message is
                POP     BC              printed.
```

The 'new name' is printed and as this is done the 'old' and the 'new' names are compared.

```
                PUSH    IX              Make the DE register pair
                POP     DE              point to the 'new type' and
                LD      HL,+FFF0        the HL register pair to the
                ADD     HL,DE           'old name'.
                LD      B,+0A           Ten characters are to be
                                        considered.
                LD      A,(HL)          Jump forward if the match is
                INC     A               to be against an actual name.
                JR      NZ,07A6,LD-NAME
                LD      A,C             But if the 'old name' is 'null'
                ADD     A,B             then signal 'ten characters
                LD      C,A             already match'.
```

A loop is entered to print the characters of the 'new name'. The name will be accepted if the 'counter' reaches zero, at least.

```
07A6    LD-NAME INC     DE              Consider each character of the
                LD      A,(DE)          'new name' in turn.
                CP      (HL)            Match it against the appropriate
                INC     HL              character of the 'old name'.
                JR      NZ,07AD,LD-CH-PR Do not count it if it does not
                INC     C               does not match.
07AD    LD-CH-PR RST    0010,PRINT-A-1  Print the 'new' character.
                DJNZ    07A6,LD-NAME    Loop for ten characters.
                BIT     7,C             Accept the name only if the
                JR      NZ,0767,LD-LOOK-H counter has reached zero.
```

```
                LD      A,+0D           Follow the 'new name' with
                RST     0010,PRINT-A-1  a 'carriage return'.
```

The correct header has been found and the time has come to consider the three commands LOAD, VERIFY, & MERGE separately.

```
                POP     HL              Fetch the pointer.
                LD      A,(IX+00)       'SCREEN$ and CODE' are
                CP      +03             handled with VERIFY.
                JR      Z,07CB,VR-CONTRL
                LD      A,(T-ADDR-lo)   Jump forward if using a
                DEC     A               LOAD command.
                JP      Z,0808,LD-CONTRL
                CP      +02             Jump forward if using a MERGE
                JP      Z,08B6,ME-CONTRL command; continue with a
                                        VERIFY command.
```

THE 'VERIFY' CONTROL ROUTINE

The verification process involves the LOADing of a block of data, a byte at a time, but the bytes are not stored - only checked. This routine is also used to LOAD blocks of data that have been described with 'SCREEN$ & CODE'.

```
07CB    VR-CONTRL   PUSH    HL              Save the 'pointer'.
                    LD      L,(IX-06)       Fetch the 'number of bytes'
                    LD      H,(IX-05)       as described in the 'old' header.
                    LD      E,(IX+0B)       Fetch also the number from the
                    LD      D,(IX+0C)       'new' header.
                    LD      A,H             Jump forward if the 'length' is
                    OR      L               unspecified.
                    JR      Z,07E9,VR-CONT-1 e.g. 'LOAD name CODE' only.
                    SBC     HL,DE           Give report R if attempting
                    JR      C,0806,REPORT-R to LOAD a larger block than has
                                            been requested.
                    JR      Z,07E9,VR-CONT-1 Accept equal 'lengths'.
                    LD      A,(IX+00)       Also give report R if trying
                    CP      +03             to VERIFY blocks that are of
                    JR      NZ,0806,REPORT-R unequal size. ('Old length'
                                            greater than 'new length'.)
```

The routine continues by considering the 'destination pointer'.

```
07E9    VR-CONT-1   POP     HL              Fetch the 'pointer', i.e. the
                                            'start'.
                    LD      A,H             This 'pointer' will be used
                    OR      L               unless it is zero, in which
                    JR      NZ,07F4,VR-CONT-2 case the 'start' found in
                    LD      L,(IX+0D)       the 'new' header will be used
                    LD      H,(IX+0E)       instead.
```

The VERIFY/LOAD flag is now considered and the actual LOAD made.

```
07F4    VR-CONT-2   PUSH    HL              Move the 'pointer' to the
                    POP     IX              IX register pair.
                    LD      A,(T-ADDR-lo)   Jump forward unless using
                    CP      +02             the VERIFY command; with
                    SCF                     the carry flag signalling
                    JR      NZ,0800,VR-CONT-3 'LOAD'
                    AND     A               Signal 'VERIFY'.
0800    VR-CONT-3   LD      A,+FF           Signal 'accept data block only'
                                            before LOADing the block.
```

THE 'LOAD A DATA BLOCK' SUBROUTINE

This subroutine is common to all the 'LOADing' routines. In the case of LOAD & VERIFY it acts as a full return from the cassette handling routines but in the case of MERGE the data block has yet to be 'MERGEd'.

```
0802    LD-BLOCK    CALL    0556,LD-BYTES   LOAD/VERIFY a data block.
                    RET     C               Return unless an error.
```

Report R - Tape loading error

```
0806    REPORT-R    RST     0008,ERROR-1        Call the error handling
                    DEFB    +1A                 routine.
```

THE 'LOAD' CONTROL ROUTINE
This routine controls the LOADing of a BASIC program, and its variables, or an array.

```
0808    LD-CONTRL   LD      E,(IX+0B)           Fetch the 'number of bytes'
                    LD      D,(IX+0C)           as given in the 'new header'.
                    PUSH    HL                  Save the 'destination pointer'.
                    LD      A,H                 Jump forward unless trying
                    OR      L                   to LOAD a previously
                    JR      NZ,0819,LD-CONT-1   undeclared array.
                    INC     DE                  Add three bytes to the
                    INC     DE                  length - for the name, the
                    INC     DE                  low length & the high length
                    EX      DE,HL               of a new variable.
                    JR      0825,LD-CONT-2      Jump forward.
```

Consider now if there is enough room in memory for the new data block.

```
0819    LD-CONT-1   LD      L,(IX-06)           Fetch the size of the existing
                    LD      H,(IX-05)           'program+variables or array'.
                    EX      DE,HL
                    SCF                         Jump forward if no extra
                    SBC     HL,DE               room will be required; taking
                    JR      C,082E,LD-DATA      into account the reclaiming of
                                                the presently used memory.
```

Make the actual test for room.

```
0825    LD-CONT-2   LD      DE,+0005            Allow an overhead of five
                    ADD     HL,DE               bytes.
                    LD      B,H                 Move the result to the
                    LD      C,L                 BC register pair and make
                    CALL    1F05,TEST-ROOM      the test.
```

Now deal with the LOADing of arrays.

```
082E    LD-DATA     POP     HL                  Fetch the 'pointer' anew.
                    LD      A,(IX+00)           Jump forward if LOADing
                    AND     A                   a BASIC program.
                    JR      Z,0873,LD-PROG
                    LD      A,H                 Jump forward if LOADing a
                    OR      L                   new array.
                    JR      Z,084C,LD-DATA-1
                    DEC     HL                  Fetch the 'length' of the
                    LD      B,(HL)              existing array by collecting
                    DEC     HL                  the length bytes from the
                    LD      C,(HL)              variables area.
                    DEC     HL                  Point to its old name.
                    INC     BC                  Add three bytes to the
                    INC     BC                  length - one for the name
                    INC     BC                  and two for the 'length'.
                    LD      (X-PTR),IX          Save the IX register pair
                    CALL    19E8,RECLAIM-2      temporarily whilst the old
                    LD      IX,(X-PTR)          array is reclaimed.
```

Space is now made available for the new array - at the end of the present variables area.

```
084C    LD-DATA-1   LD      HL,(E-LINE)         Find the pointer to the
                    DEC     HL                  end-marker of the variables
                                                area - the '80-byte'.
                    LD      C,(IX+0B)           Fetch the 'length' of the
                    LD      B,(IX+0C)           new array.
                    PUSH    BC                  Save this 'length'.
```

```
                INC     BC              Add three bytes - one for
                INC     BC              the name and two for the
                INC     BC              'length'.
                LD      A,(IX-03)       'IX+0E' of the old header
                                        gives the name of the array.
                PUSH    AF              The name is saved whilst the
                CALL    1655,MAKE-ROOM  appropriate amount of room is
                INC     HL              made available. In effect 'BC'
                POP     AF              spaces before the 'new 80-byte'.
                LD      (HL),A          The name is entered.
                POP     DE              The 'length' is fetched and
                INC     HL              its two bytes are also
                LD      (HL),E          entered.
                INC     HL
                LD      (HL),D
                INC     HL              HL now points to the first
                                        location that is to be filled
                                        with data from the tape.
                PUSH    HL              This address is moved to the
                POP     IX              IX register pair; the carry
                SCF                     flag set; 'data block' is
                LD      A,+FF           signalled; and the block
                JP      0802,LD-BLOCK   LOADed.
```

Now deal with the LOADing of a BASIC program and its variables

```
0873    LD-PROG EX      DE,HL           Save the 'destination pointer'.
                LD      HL,(E-LINE)     Find the address of the
                DEC     HL              end-marker of the current
                                        variables area - the '80-byte'.
                LD      (X-PTR),IX      Save IX temporarily.
                LD      C,(IX+0B)       Fetch the 'length' of the
                LD      B,(IX+0C)       new data block.
                PUSH    BC              Keep a copy of the 'length'
                CALL    19E5,RECLAIM-1  whilst the present program and
                POP     BC              variables areas are reclaimed.
                PUSH    HL              Save the pointer to the program
                PUSH    BC              area and the length of the new
                                        data block.
                CALL    1655,MAKE-ROOM  Make sufficient room available
                                        for the new program and its
                                        variables.
                LD      IX,(X-PTR)      Restore the IX register pair.
                INC     HL              The system variable VARS
                LD      C,(IX+0F)       has also to be set for the
                LD      B,(IX+10)       new program.
                ADD     HL,BC
                LD      (VARS),HL
                LD      H,(IX+0E)       If a line number was
                LD      A,H             specified then it too has to
                AND     +C0             be considered.
                JR      NZ,08AD,LD-PROG-1 Jump if 'no number'; otherwise
                LD      L,(IX+0D)       set NEWPPC & NSPPC.
                LD      (NEWPPC),HL
                LD      (NSPPC),+00
```

The data block can now be LOADed.

```
08AD    LD-PROG-1 POP   DE              Fetch the 'length'.
                POP     IX              Fetch the 'start'.
                SCF                     Signal 'LOAD'.
                LD      A,+FF           Signal 'data block' only.
                JP      0802,LD-BLOCK   Now LOAD it.
```

THE 'MERGE' CONTROL ROUTINE

There are three main parts to this routine.

I. LOAD the data block into the work space.
II. MERGE the lines of the new program into the old program.
III. MERGE the new variables into the old variables.

Start therefore with the LOADing of the data block.

```
08B6    ME-CONTRL   LD      C,(IX+0B)       Fetch the 'length' of the
                    LD      B,(IX+0C)       data block.
                    PUSH    BC              Save a copy of the 'length'.
                    INC     BC              Now made 'length+1' locations
                    RST     0030,BC-SPACES  available in the work space.
                    LD      (HL),+80        Place an end-marker in the
                                            extra location.
                    EX      DE,HL           Move the 'start' pointer to the
                                            HL register pair.
                    POP     DE              Fetch the original 'length'.
                    PUSH    HL              Save a copy of the 'start'.
                    PUSH    HL              Now set the IX register pair
                    POP     IX              for the actual LOAD.
                    SCF                     Signal 'LOAD'.
                    LD      A,+FF           Signal 'data block only'.
                    CALL    0802,LD-BLOCK   LOAD the data block.
```

The lines of the new program are MERGEd with the lines of the old program.

```
                    POP     HL              Fetch the 'start' of the new
                                            program.
                    LD      DE,(PROG)       Initialise DE to the 'start' of
                                            the old program.
```

Enter a loop to deal with the lines of the new program.

```
08D2    ME-NEW-LP   LD      A,(HL)          Fetch a line number and test
                    AND     +C0             it.
                    JR      NZ,08F0,ME-VAR-LP  Jump when finished with all
                                            the lines.
```

Now enter an inner loop to deal with the lines of the old program.

```
08D7    ME-OLD-LP   LD      A,(DE)          Fetch the high line number
                    INC     DE              byte and compare it.
                    CP      (HL)            Jump forward if it does not
                    INC     HL              match but in any case advance
                    JR      NZ,08DF,ME-OLD-L1  both pointers.
                    LD      A,(DE)          Repeat the comparison for the
                    CP      (HL)            low line number bytes.
08DF    ME-OLD-L1   DEC     DE              Now retreat the pointers.
                    DEC     HL
                    JR      NC,08EB,ME-NEW-L2  Jump forward if the correct
                                            place has been found for a line
                                            of the new program.
                    PUSH    HL              Otherwise find the address of
                    EX      DE,HL           the start of the next old line.
                    CALL    19B8,NEXT-ONE
                    POP     HL
                    JR      08D7,ME-OLD-LP  Go round the loop for each of
                                            the 'old lines'.
08EB    ME-NEW-L2   CALL    092C,ME-ENTER   Enter the 'new line' and go
                    JR      08D2,ME-NEW-LP  round the outer loop again.
```

In a similar manner the variables of the new program are MERGEd with the variables of the old program.
A loop is entered to deal with each of the new variables in turn.

```
08F0    ME-VAR-LP   LD      A,(HL)          Fetch each variable name in
```

```
                LD      C,A             turn and test it.
                CP      +80             Return when all the variables
                RET     Z               have been considered.
                PUSH    HL              Save the current new pointer.
                LD      HL,(VARS)       Fetch VARS (for the old
                                        program).
```

Now enter an inner loop to search the existing variables area.

```
08F9    ME-OLD-VP   LD      A,(HL)          Fetch each variable name and
                    CP      +80             test it.
                    JR      Z,0923,ME-VAR-L2 Jump forward once the end
                                            marker is found. (Make an
                                            'addition'.)
                    CP      c               Compare the names 0 st. bytes).
                    JR      Z,0909,ME-OLD-v2 Jump forward to consider it
                                            further; returning here if it
                                            proves not to match fully.
0901    ME-OLD-V1   PUSH    BC              Save the new variable's name
                    CALL    19B8,NEXT-ONE   whilst the next 'old variable'
                    POP     BC              is located.
                    EX      DE,HL           Restore the pointer to the
                    JR      08F9,ME-OLD-VP  D E register pair and go round
                                            the loop again.
```

The old and new variables match with respect to their first bytes but variables with long names will need to be matched fully.

```
0909    ME-OLD-V2   AND     +E0             Consider bits 7, 6 & 5 only.
                    CP      +A0             Accept all the variable types
                    JR      NZ,0921,ME-VAR-L1 except 'long named variables'.
                    POP     DE              Make DE point to the first
                    PUSH    DE              character of the 'new name'.
                    PUSH    HL              Save the pointer to the 'old
                                            name'.
```

Enter a loop to compare the letters of the long names.

```
0912    ME-OLD-V3   INC     HL              Update both the 'old' and the
                    INC     DE              'new' pointers.
                    LD      A,(DE)          Compare the two letters
                    CP      (HL)
                    JR      NZ,091E,ME-OLD-V4 Jump forward if the match
                                            fails.
                    RLA                     Go round the loop until the
                    JR      NC,0912,ME-OLD-V3 'last character' is found.
                    POP     HL              Fetch the pointer to the
                                            start of the 'old' name and
                    JR      0921,ME-VAR-L1  jump forward - successful.
091E    ME-OLD-V4   POP     HL              Fetch the pointer and jump
                    JR      0901,ME-OLD-V1  back - unsuccessful.
```

Come here if the match was found.

```
0921    ME-VAR-L1   LD      A,+FF           Signal 'replace' variable.
```

And here if not. (A holds +80 - variable to be 'added'.)

```
0923    ME-VAR-L2   POP     DE              Fetch pointer to 'new' name.
                    EX      DE,HL           Switch over the registers.
                    INC     A               The zero flag is to be set if there
                                            is to be a 'replacement'; reset
                                            for an 'addition'.
                    SCF                     Signal 'handling variables'.
                    CALL    092C,ME-ENTER   Now make the entry.
                    JR      08F0,ME-VAR-LP  Go round the loop to consider
                                            the next new variable.
```

THE 'MERGE A LINE OR A VARIABLE' SUBROUTINE

This subroutine is entered with the following parameters:

Carry flag	reset	- MERGE a BASIC line.	
	set	- MERGE a variable.	
Zero		reset	- It will be an 'addition'.
		set	- It is a 'replacement'.
HL register pair			- Points to the start of the new entry.
DE register pair			- Points to where it is to MERGE.

```
092C    ME-ENTER    JR      NZ,093E,ME-ENT-1    Jump if handling an 'addition'.
                    EX      AF,A'F'             Save the flags.
                    LD      (X-PTR),HL          Save the 'new' pointer whilst
                    EX      DE,HL               the 'old' line or variable
                    CALL    19B8,NEXT-ONE       is reclaimed.
                    CALL    19E8,RECLAIM-2
                    EX      DE,HL
                    LD      HL,(X-PTR)
                    EX      AF,A'F'             Restore the flags.
```

The new entry can now be made.

```
093E    ME-ENT-1    EX      AF,A'F'             Save the flags.
                    PUSH    DE                  Make a copy of the
                                                'destination' pointer.
                    CALL    19B8,NEXT-ONE       Find the length of the 'new'
                                                variable/line.
                    LD      (X-PTR),HL          Save the pointer to the 'new'
                                                variable/line.
                    LD      HL,(PROG)           Fetch PROG - to avoid
                                                corruption.
                    EX      (SP),HL             Save PROG on the stack and
                                                fetch the 'new' pointer.
                    PUSH    BC                  Save the length.
                    EX      AF,A'F'             Retrieve the flags.
                    JR      C,0955,ME-ENT-2     Jump forward if adding a new
                                                variable.
                    DEC     HL                  A new line is added before the
                                                'destination' location.
                    CALL    1655,MAKE-ROOM      Make the room for the new line.
                    INC     HL
                    JR      0958,ME-ENT-3       Jump forward.
0955    ME-ENT-2    CALL    1655,MAKE-ROOM      Make the room for the new
                                                variable.
0958    ME-ENT-3    INC     HL                  Point to the 1st new location.
                    POP     BC                  Retrieve the length.
                    POP     DE                  Retrieve PROG and store it
                    LD      (PROG),DE           in its correct place.
                    LD      DE,(X-PTR)          Also fetch the 'new' pointer.
                    PUSH    BC                  Again save the length and the
                    PUSH    DE                  new' pointer.
                    EX      DE,HL               Switch the pointers and copy
                    LDIR                        the 'new' variable/line into the
                                                room made for it.
```

The 'new' variable/line has now to be removed from the work space.

```
                    POP     HL                  Fetch the 'new' pointer.
                    POP     BC                  Fetch the length.
                    PUSH    DE                  Save the 'old' pointer. (Points
                                                to the location after the 'added'
                                                variable/line.)
                    CALL    19E8,RECLAIM-2      Remove the variable/line from
                                                the work space.
                    POP     DE                  Return with the 'old' pointer
                    RET                         in the DE register pair.
```

THE 'SAVE' CONTROL ROUTINE

The operation of SAVing a program or a block of data is very straightforward.

```
0970    SA-CONTRL   PUSH    HL              Save the 'pointer'.
                    LD      A,+FD           Ensure that channel 'K'
                    CALL    1601,CHAN-OPEN  is open.
                    XOR     A               Signal 'first message'.
                    LD      DE,+09A1        Print the message - Start tape,
                    CALL    0C0A,PO-MSG     then press any key.'.
                    SET     5,(TV-FLAG)     Signal 'screen will require to be
                                            cleared'.
                    CALL    15D4,WAIT-KEY   Wait for a key to be pressed.
```

Upon receipt of a keystroke the 'header' is saved.

```
                    PUSH    IX              Save the base address of the
                                            'header' on the machine stack.
                    LD      DE,+0011        Seventeen bytes are to be
                                            SAVEd.
                    XOR     A               Signal 'It is a header'.
                    CALL    04C2,SA-BYTES   Send the 'header'; with a leading
                                            'type' byte and a trailing 'parity'
                                            byte.
```

There follows a short delay before the program/data block is SAVEd.

```
                    POP     IX              Retrieve the pointer to the
                                            'header'.
                    LD      B,+32           The delay is for fifty
0991    SA-1-SEC    HALT                    interrupts, i.e. one second.
                    DJNZ    0991,SA-1-SEC
                    LD      E,(IX+0B)       Fetch the length of the
                    LD      D,(IX+0C)       data block that is to be SAVEd.
                    LD      A,+FF           Signal 'data block'.
                    POP     IX              Fetch the 'start of block
                    JP      04C2,SA-BYTES   pointer' and SAVE the block.
```

THE CASSETTE MESSAGES

Each message is given with the last character inverted (+80 hex.).

```
09A1    DEFB +80    - Initial byte is stepped over.
09A2    DEFM        - Start tape, then press any key.
09C1    DEFM        - 'carriage return' - Program:
09CB    DEFM        - 'carriage return' - Number array:
09DA    DEFM        - 'carriage return' - Character array:
09EC    DEFM        - 'carriage return' - Bytes:
```

THE SCREEN & PRINTER HANDLING ROUTINES

THE 'PRINT-OUT' ROUTINES

All of the printing to the main part of the screen, the lower part of the screen and the printer is handled by this set of routines. The PRINT-OUT routine is entered with the A register holding the code for a control character, a printable character or a token.

```
09F4    PRINT-OUT   CALL    0B03,PO-FETCH       The current print position.
                    CP      +20                 If the code represents a
                    JP      NC,0AD9,PO-ABLE     printable character then jump.
                    CP      +06                 Print a question mark for
                    JR      C,0A69,PO-QUEST     codes in the range +00 - +05.
                    CP      +18                 And also for codes +18 - +1F.
                    JR      NC,0A69,PO-QUEST
                    LD      HL,+0A0B            Base of 'control' table.
                    LD      E,A                 Move the code to the
                    LD      D,+00               DE register pair.
                    ADD     HL,DE               Index into the table and
                    LD      E,(HL)              fetch the offset.
                    ADD     HL,DE               Add the offset and make
                    PUSH    HL                  an indirect jump to the
                    JP      0B03,PO-FETCH       appropriate subroutine.
```

THE 'CONTROL CHARACTER' TABLE

address	offset	character	address	offset	character
0A11	4E	PRINT comma	0A1A	4F	not used
0A12	57	EDIT	0A1B	5F	INK control
0A13	10	cursor left	0A1C	5E	PAPER control
0A14	29	cursor right	0A1D	5D	FLASH control
0A15	54	cursor down	0A1E	5C	BRIGHT control
0A16	53	cursor up	0A1F	5B	INVERSE control
0A17	52	DELETE	0A20	5A	OVER control
0A18	37	ENTER	0A21	54	AT control
0A19	50	not used	0A22	53	TAB control

THE 'CURSOR LEFT' SUBROUTINE

The subroutine is entered with the B register holding the current line number and the C register with the current column number.

```
0A23    PO-BACK-1   INC     C                   Move leftwards by one column.
                    LD      A,+22               Accept the change unless
                    CP      C                   up against the lefthand side.
                    JR      NZ,0A3A,PO-BACK-3
                    BIT     1,(FLAGS)           If dealing with the printer
                    JR      NZ,0A38,PO-BACK-2   jump forward.
                    INC     B                   Go up one line.
                    LD      C,+02               Set column value.
                    LD      A,+18               Test against top line.
                    CP      B                   Note: This ought to be +19.
                    JR      NZ,0A3A,PO-BACK-3   Accept the change unless at
                                                the top of the screen.
                    DEC     B                   Unacceptable so down a line.
0A38    PO-BACK-2   LD      C,+21               Set to lefthand column.
0A3A    PO-BACK-3   JP      0DD9,CL-SET         Make an indirect return via
                                                CL-SET & PO-STORE.
```

THE 'CURSOR RIGHT' SUBROUTINE

This subroutine performs an operation identical to the BASIC statement – PRINT OVER 1;CHR$ 32; -.

```
0A3D    PO-RIGHT    LD      A,(P-FLAG)          Fetch P-FLAG and save it on
                    PUSH    AF                  the machine stack.
```

```
                LD      (P-FLAG),+01    Set P-FLAG to OVER 1.
                LD      A,+20           A 'space'.
                CALL    0B65,PO-CHAR    Print the character.
                POP     AF              Fetch the old value of
                LD      (P-FLAG),A      P-FLAG.
                RET                     Finished.
                                        Note: The programmer has
                                        forgotten to exit via PO-STORE.
```

THE 'CARRIAGE RETURN' SUBROUTINE

If the printing being handled is going to the printer then a carriage return character leads to the printer buffer being emptied. If the printing is to the screen then a test for 'scroll?' is made before decreasing the line number.

```
0A4F    PO-ENTER    BIT     1,(FLAGS)           Jump forward if handling
                    JP      NZ,0ECD,COPY-BUFF   the printer.
                    LD      C,+21               Set to lefthand column.
                    CALL    0C55,PO-SCR         Scroll if necessary.
                    DEC     B                   Now down a line.
                    JP      0DD9,CL-SET         Make an indirect return via
                                                CL-SET & PO-STORE.
```

THE 'PRINT COMMA' SUBROUTINE

The current column value is manipulated and the A register set to hold +00 (for TAB 0) or +10 (for TAB 16).

```
0A5F    PO-COMMA    CALL    0B03,PO-FETCH       Why again?
                    LD      A,C                 Current column number.
                    DEC     A                   Move rightwards by two
                    DEC     A                   columns and then test.
                    AND     +10                 The A register will be +00 or
                                                +10.
                    JR      0AC3,PO-FILL        Exit via PO-FILL.
```

THE 'PRINT A QUESTION MARK' SUBROUTINE

A question mark is printed whenever an attempt is made to print an unprintable code.

```
0A69    PO-QUEST    LD      A,+3F               The character '?'.
                    JR      0AD9,PO-ABLE        Now print this character instead.
```

THE 'CONTROL CHARACTERS WITH OPERANDS' ROUTINE

The control characters from INK to OVER require a single operand whereas the control characters AT & TAB are required to be followed by two operands.
The present routine leads to the control character code being saved in TVDATA-lo, the first operand in TVDATA-hi or the A register if there is only a single operand required, and the second operand in the A register.

```
0A6D    PO-TV-2     LD      DE,+0A87            Save the first operand in
                    LD      (TVDATA-hi),A       TVDATA-hi and change the
                    JR      0A80,PO-CHANGE      address of the 'output' routine
                                                to PO-CONT (+0A87).
```

Enter here when handling the characters AT & TAB.

```
0A75    PO-2-OPER   LD      DE,+0A6D            The character code will be
                    JR      0A7D,PO-TV-1        saved in TVDATA-lo and the
                                                address of the 'output' routine
                                                changed to PO-TV-2 (+0A6D).
```

Enter here when handling the colour items - INK to OVER.

```
0A7A    PO-1-OPER   LD      DE,+0A87            The 'output' routine is to be
                                                changed to PO-CONT (+0A87).
0A7D    PO-TV-1     LD      (TVDATA-lo),A       Save the control character code.
```

The current 'output' routine address is changed temporarily.

```
0A80  PO-CHANGE  LD    HL,(CURCHL)     HL will point to the 'output'
                                       routine address.
                 LD    (HL),E          Enter the new 'output'
                 INC   HL              routine address and thereby
                 LD    (HL),D          force the next character code
                 RET                   to be considered as an operand.
```

Once the operands have been collected the routine continues.

```
0A87  PO-CONT    LD    DE,+09F4        Restore the original address
                 CALL  0A80,PO-CHANGE  for PRINT-OUT (+09F4).
                 LD    HL,(TVDATA)     Fetch the control code and the
                                       first operand if there are indeed
                                       two operands.
                 LD    D,A             The 'last' operand and the
                 LD    A,L             control code are moved.
                 CP    +16             Jump forward if handling
                 JP    C,2211,CO-TEMPS INK to OVER.
                 JR    NZ,0AC2,PO-TAB  Jump forward if handling TAB.
```

Now deal with the AT control character.

```
                 LD    B,H             The line number.
                 LD    C,D             The column number.
                 LD    A,+1F           Reverse the column number;
                 SUB   C               i.e. +00 - +1F becomes +1F -
                                       +00.
                 JR    C,0AAC,PO-AT-ERR Must be in range.
                 ADD   A,+02           Add in the offset to give
                 LD    C,A             C holding +21 - +22.
                 BIT   1,(FLAGS)       Jump forward if handling the
                 JR    NZ,0ABF,PO-AT-SET printer.
                 LD    A,+16           Reverse the line number;
                 SUB   B               i.e. +00 - +15 becomes +16 -
                                       +01.
0AAC  PO-AT-ERR  JP    C,1E9F,REPORT-B If appropriate jump forward.
                 INC   A               The range +16 - +01 becomes
                 LD    B,A             +17 - +02.
                 INC   B               And now +18 - +03.
                 BIT   0,(TV-FLAG)     If printing in the lower part
                 JP    NZ,0C55,PO-SCR  of the screen then consider
                                       whether scrolling is needed.
                 CP    (DF-SZ)         Give report 5 - Out of screen,
                 JP    C,0C86,REPORT-5 if required.
0ABF  PO-AT-SET  JP    0D09,CL-SET     Return via CL-SET & PO-STORE.
```

And the TAB control character.

```
0AC2  PO-TAB     LD    A,H             Fetch the first operand.
0AC3  PO-FILL    CALL  0B03,PO-FETCH   The current print position.
                 ADD   A,C             Add the current column value.
                 DEC   A               Find how many 'spaces', modulo
                 AND   +1F             32, are required and return
                 RET   Z               if the result is zero.
                 LD    D,A             Use 0 as the counter.
                 SET   0,(FLAGS)       Suppress 'leading space'.
0AD0  PO-SPACE   LD    A,+20           Print 'D number' of
                 CALL  0C3B,PO-SAVE    spaces.
                 DEC   D
                 JR    NZ,0AD0,PO-SPACE
                 RET                   Now finished.
```

PRINTABLE CHARACTER CODES.

The required character (or characters) is printed by calling PO-ANY followed by PO-STORE.

```
0AD9    PO-ABLE     CALL    0B24,PO-ANY     Print the character(s)
                                            and continue into PO-STORE.
```

THE 'POSITION STORE' SUBROUTINE

The new position's 'line & column' values and the 'pixel' address are stored in the appropriate system variables.

```
0ADC    PO-STORE    BIT     1,(FLAGS)       Jump forward if handling
                    JR      NZ,0AFC,PO-ST-PR the printer.
                    BIT     0,(TV-FLAG)     Jump forward if handling the
                    JR      NZ,0AF0,PO-ST-E lower part of the screen.
                    LD      (S-POSN),BC     Save the values that relate
                    LD      (DF-CC),HL      to the main part of the
                    RET                     screen. Then return.
0AF0    PO-ST-E     LD      (S-POSNL),BC    Save the values that relate
                    LD      (ECHO-E),BC     to the lower part of the
                    LD      (DF-CCL),HL     screen.
                    RET                     Then return.
0AFC    PO-ST-PR    LD      (P-POSN),C      Save the values that relate
                    LD      (PR-CC),HL      to the printer buffer.
                    RET                     Then return.
```

THE 'POSITION FETCH' SUBROUTINE

The current position's parameters are fetched from the appropriate system variables.

```
0B03    PO-FETCH    BIT     1,(FLAGS)       Jump forward if handling
                    JR      NZ,0B1D,PO-F-PR the printer.
                    LD      BC,(S-POSN)     Fetch the values relating
                    LD      HL,(DF-CC)      to the main part of the
                    BIT     0,(TV-FLAG)     screen and return if this
                    RET     Z               was the intention.
                    LD      BC,(S-POSNL)    Otherwise fetch the values
                    LD      HL,(DF-CCL)     relating to the lower part
                    RET                     of the screen.
0B1D    PO-F-PR     LD      C,(P-POSN)      Fetch the values relating
                    LD      HL,(PR-CC)      to the printer buffer.
                    RET
```

THE 'PRINT ANY CHARACTER(S)' SUBROUTINE

Ordinary character codes, token codes and user-defined graphic codes, and graphic codes are dealt with separately.

```
0B24    PO-ANY      CP      +80             Jump forward with ordinary
                    JR      C,0B65,PO-CHAR  character codes.
                    CP      +90             Jump forward with token
                    JR      NC,0B52,PO-T&UDG codes and UDG codes.
                    LD      B,A             Move the graphic code.
                    CALL    0B38,PO-GR-1    Construct the graphic form.
                    CALL    0B03,PO-FETCH   HL has been disturbed so
                                            'fetch' again.
                    LD      DE,+5C92        Make DE point to the start of the
                                            graphic form; i.e. MEMBOT.
                    JR      0B7F,PO-ALL     Jump forward to print the
                                            graphic character.
```

Graphic characters are constructed in an Ad Hoc manner in the calculator's memory area; i.e. MEM-0 & MEM-1.

```
0B38    PO-GR-1     LD      HL,+5C92        This is MEMBOT.
                    CALL    0B3E,PO-GR-2    In effect call the following
                                            subroutine twice.
0B3E    PO-GR-2     RR      B               Determine bit 0 (and later bit 2)
                    SBC     A,A             of the graphic code.
                    AND     +0F             The A register will hold +00 or
                                            +0F depending on the value of
                                            the bit in the code.
```

```
                    LD      C,A             Save the result in C.
                    RR      B               Determine bit 1 (and later bit 3)
                    SBC     A,A             of the graphic code.
                    AND     +F0             The A register will hold +00
                                            or +F0.
                    OR      C               The two results are combined.
                    LD      C,+04           The A register holds half the
0B4C    PO-GR-3     LD      (HL),A          character form and has to be
                    INC     HL              used four times.
                    DEC     C               This is done for the upper
                    JR      NZ,0B4C,PO-GR-3 half of the character form
                    RET                     and then the lower.
```

Token codes and user-defined graphic codes are now separated.

```
0B52    PO-T&UDG    SUB     +A5             Jump forward with token codes
                    JR      NC,0B5F,PO-T
                    ADD     A,+15           UDG codes are now +00 - +0F.
                    PUSH    BC              Save the current position
                                            values on the machine stack.
                    LD      BC,(UDG)        Fetch the base address of the
                    JR      0B6A,PO-CHAR-2  UDG area and jump forward.
0B5F    PO-T        CALL    0C10,PO-TOKENS  Now print the token and return
                    JP      0B03,PO-FETCH   via PO-FETCH.
```

The required character form is identified.

```
0B65    PO-CHAR     PUSH    BC              The current position is saved.
                    LD      BC,(CHARS)      The base address of the
                                            character area is fetched.
0B6A    PO-CHAR-2   EX      DE,HL           The print address is saved.
                    LD      HL,+5C3B        This is FLAGS.
                    RES     0,(HL)          Allow for a leading space
                    CP      +20             Jump forward if the character
                    JR      NZ,0B76,PO-CHAR-3 is not a 'space'.
                    SET     0,(HL)          But 'suppress' if it is.
0B76    PO-CHAR-3   LD      H,+00           Now pass the character code
                    LD      L,A             to the HL register pair.
                    ADD     HL,HL           The character code is in
                    ADD     HL,HL           effect multiplied by 8.
                    ADD     HL,HL
                    ADD     HL,BC           The base address of the
                                            character form is found.
                    POP     BC              The current position is fetched
                    EX      DE,HL           and the base address passed to
                                            the DE register pair.
```

THE 'PRINT ALL CHARACTERS' SUBROUTINE

This subroutine is used to print all '8*8' bit characters. On entry the DE register pair holds the base address of the character form, the HL register the destination address and the BC register pair the current 'line & column' values.

```
0B7F    PR-ALL      LD      A,C             Fetch the column number.
                    DEC     A               Move one column rightwards.
                    LD      A,+21           Jump forward unless a new
                    JR      NZ,0893,PR-ALL-1 line is indicated.
                    DEC     B               Move down one line.
                    LD      C,A             Column number is +21.
                    BIT     1,(FLAGS)       Jump forward if handling
                    JR      Z,0B93,PR-ALL-1 the screen.
                    PUSH    DE              Save the base address whilst
                    CALL    0ECD,COPY-BUFF  the printer buffer is
                    POP     DE              emptied.
                    LD      A,C             Copy the new column number.
0B93    PR-ALL-1    CP      C               Test whether a new line is
```

```
                    PUSH    DE              being used. If it is
                    CALL    Z,0C55,PO-SCR   see if the display requires
                    POP     DE              to be scrolled.
```

Now consider the present state of INVERSE & OVER'

```
                    PUSH    BC              Save the position values
                    PUSH    HL              and the destination address
                                            on the machine stack.
                    LD      A,(P-FLAG)      Fetch P-FLAG and read bit 0.
                    LD      B,+FF           Prepare the 'OVER-mask' in
                    RRA                     the B register; i.e. OVER 0
                    JR      C,0BA4,PR-ALL-2 = +00 & OVER 1 - +FF.
                    INC     B
0BA4    PR-ALL-2    RRA                     Read bit 2 of P-FLAG and
                    RRA                     prepare the 'INVERSE-mask'
                    SBC     A,A             in the C register; i.e.
                    LD      C,A             INVERSE 0 = +00 & INVERSE
                                            1 = +FF.
                    LD      A,+08           Set the A register to hold
                    AND     A               the 'pixel-line' counter and
                                            clear the carry flag.
                    BIT     1,(FLAGS)       Jump forward if handling
                    JR      Z,0BB6,PR-ALL-3 the screen.
                    SET     1,(FLAGS2)      Signal 'printer buffer no longer
                                            empty.
                    SCF                     Set the carry flag to show that
                                            the printer is being used.
0BB6    PR-ALL-3    EX      DE,HL           Exchange the destination
                                            address with the base address
                                            before entering the loop.
```

The character can now be printed. Eight passes of the loop are made - one for each 'pixel-line'.

```
0BB7    PR-ALL-4    EX      AF,A'F'         The carry flag is set when using
                                            the printer. Save this flag in F'.
                    LD      A,(DE)          Fetch the existing 'pixel-line'.
                    AND     B               Use the 'OVER-mask' and then
                    XOR     (HL)            XOR the result with the 'pixel-
                                            line' of the character form.
                    XOR     C               Finally consider the 'INVERSE-
                                            mask'.
                    LD      (DE),A          Enter the result.
                    EX      AF,A'F'         Fetch the printer flag and
                    JR      C,0BD3,PR-ALL-6 jump forward if required.
                    INC     D               Update the destination address
0BC1    PR-ALL-5    INC     HL              Update the 'pixel-line' of
                                            the character form.
                    DEC     A               Decrease the counter and loop
                    JR      NZ,0BB7,PR-ALL-4 back unless it is zero.
```

Once the character has been printed the attribute byte is to set as required.

```
                    EX      DE,HL           Make the H register hold a
                    DEC     H               correct high-address for the
                                            character area.
                    BIT     1,(FLAGS)       Set the attribute byte only if
                    CALL    Z,0BDB,PO-ATTR  handling the screen.
                    POP     HL              Restore the original
                    POP     BC              destination address and the
                                            position values.
                    DEC     C               Decrease the column number
                    INC     HL              and increase the destination
                    RET                     address before returning.
```

When the printer is being used the destination address has to be updated in increments of +20.

```
0BD3    PR-ALL-6    EX      AF,A'F'         Save the printer flag again.
                    LD      A,+20           The required increment value.
                    ADD     A,E             Add the value and pass the
                    LD      E,A             result back to the E register.
                    EX      AF,A'F'         Fetch the flag.
                    JR      0BC1,PR-ALL-5   Jump back into the loop.
```

THE 'SET ATTRIBUTE BYTE' SUBROUTINE

The appropriate attribute byte is identified and fetched. The new value is formed by manipulating the old value, ATTR-T, MASK-T and P-FLAG. Finally this new value is copied to the attribute area.

```
0BDB    PO-ATTR     LD      A,H             The high byte of the
                    RRCA                    destination address is
                    RRCA                    divided by eight and ANDed
                    RRCA                    with +03 to determine which
                    AND     +03             third of the screen is being
                                            addressed; i.e. 00,01 or 02.
                    OR      +58             The high byte for the
                    LD      H,A             attribute area is then formed.
                    LD      DE,(ATTR-T)     D holds ATTR-T, and
                                            E holds MASK-T.
                    LD      A,(HL)          The old attribute value.
                    XOR     E               The values of MASK-T and
                    AND     D               ATTR-R are taken into
                    XOR     E               account.
                    BIT     6,(P-FLAG)      Jump forward unless dealing
                    JR      Z,0BFA,PO-ATTR-1 with PAPER 9.
                    AND     +C7             The old paper colour is ignored
                                            and depending on whether the
                    BIT     2,A             ink colour is light or dark
                    JR      NZ,0BFA,PO-ATTR-1 the new paper colour will be
                    XOR     +38             black (000) or white (111).
0BFA    PO-ATTR-1   BIT     4,(P-FLAG)      Jump forward unless dealing
                    JR      Z,0C08,PO-ATTR-2 with INK 9.
                    AND     +F8             The old ink colour is ignored and
                                            depending on whether the paper
                    BIT     5,A             colour is light or dark the new
                    JR      NZ,0C08,PO-ATTR-2 ink colour will be black (000)
                    XOR     +07             or white (111).
0C08    PO-ATTR-2   LD      (HL),A          Enter the new attribute value
                    RET                     and return.
```

THE 'MESSAGE PRINTING' SUBROUTINE

This subroutine is used to print messages and tokens. The A register holds the 'entry number' of the message or token in a table. The DE register pair holds the base address of the table.

```
0C0A    PO-MSG      PUSH    HL              The high byte of the last
                    LD      H,+00           entry on the machine stack is
                    EX      (SP),HL         made zero so as to suppress
                                            trailing spaces (see below).
                    JR      0C14,PO-TABLE   Jump forward.
```

Enter here when expanding token codes.

```
0C10    PO-TOKENS   LD      DE,+0095        The base address of the token
                                            table.
                    PUSH AF     Save the code on the stack.
                                            (Range +00 - +5A; RND - COPY).
```

The table is searched and the correct entry printed.

```
0C14    PO-TABLE    CALL    0C41,PO-SEARCH  Locate the required entry.
                    JR      C,0C22,PO-EACH  Print the message/token.
                    LD      A,+20           A 'space' will be printed
```

```
                BIT     0,(FLAGS)           before the message/token
                CALL    Z,0C3B,PO-SAVE      if required.
```

The characters of the message/token are printed in turn.

```
0C22    PO-EACH LD      A,(DE)              Collect a code.
                AND     +7F                 Cancel any 'inverted bit'.
                CALL    0C3B,PO-SAVE        Print the character.
                LD      A,(DE)              Collect the code again.
                INC     DE                  Advance the pointer.
                ADD     A,A                 The 'inverted bit' goes to
                JR      NC,0C22,PO-EACH     the carry flag and signals
                                            the end of the message/token;
                                            otherwise jump back.
```

Now consider whether a 'trailing space' is required.

```
                POP     DE                  For messages - D holds +00;
                                            for tokens - D holds +00 - +5A.
                CP      +48                 Jump forward if the last
                JR      Z,0C35,PO-TRSP      character was a '$'.
                CP      +82                 Return if the last character
                RET     C                   was any other before 'A'.
0C35    PO-TR-SP LD     A,D                 Examine the value in D and
                CP      +03                 return if it indicates a
                RET     C                   message, RND, INKEY$ or PI.
                LD      A,+20               All other cases will require
                                            a 'trailing space'.
```

THE 'PO-SAVE' SUBROUTINE

This subroutine allows for characters to be printed 'recursively'. The appropriate registers are saved whilst 'PRINT-OUT' is called.

```
0C3B    PO-SAVE PUSH    DE                  Save the DE register pair.
                EXX                         Save HL & BC.
                RST     0010,PRINT-A-1      Print the single character.
                EXX                         Restore HL & BC.
                POP     DE                  Restore DE.
                RET                         Finished.
```

THE 'TABLE SEARCH' SUBROUTINE

The subroutine returns with the DE register pair pointing to the initial character of the required entry and the carry flag reset if a 'leading space' is to be considered.

```
0C41    PO-SEARCH PUSH  AF                  Save the 'entry number'.
                EX      DE,HL               HL now holds the base address.
                INC     A                   Make the range +01 - ?.
0C44    PO-STEP BIT     7,(HL)              Wait for an 'inverted
                INC     HL                  character'.
                JR      Z,0C44,PO-STEP
                DEC     A                   Count through the entries
                JR      NZ,0C44,PO-STEP     until the correct one is found.
                EX      DE,HL               DE points to the initial character.
                POP     AF                  Fetch the 'entry number' and
                CP      +20                 return with carry set for the
                RET     C                   first thirty two entries.
                LD      A,(DE)              However if the initial
                SUB     +41                 character is a letter then a
                RET                         leading space may be needed.
```

THE 'TEST FOR SCROLL' SUBROUTINE

This subroutine is called whenever there might be the need to scroll the display. This occurs on three occasions; i. when handling a 'carriage return' character; ii. when using AT in an INPUT line; & iii. when the current line is full and the next line has to be used.
On entry the B register holds the line number under test.

```
0C55  PO-SCR    BIT   1,(FLAGS)          Return immediately if the
                RET   NZ                 printer is being used.
                LD    DE,+0DD9           Pre-load the machine stack
                PUSH  DE                 with the address of 'CL-SET'.
                LD    A,B                Transfer the line number.
                BIT   0,(TV-FLAG)        Jump forward if considering
                JP    NZ,0D02,PO-SCR-4   'INPUT ... AT ..'.
                CP    (DF-SZ)            Return, via CL-SET, if the line
                JR    C,0C86,REPORT-6    number is greater than the value
                RET   NZ                 of DF-SZ; give report 5 if it is
                                         less; otherwise continue.
                BIT   4,(TV-FLAG)        Jump forward unless dealing
                JR    Z,0C88,PO-SCR-2    with an 'automatic listing'.
                LD    E,(BREG)           Fetch the line counter.
                DEC   E                  Decrease this counter.
                JR    Z,0CD2,PO-SCR-3    Jump forward if the listing
                                         is to be scrolled.
                LD    A,+00              Otherwise open channel 'K',
                CALL  1601,CHAN-OPEN     restore the stack pointer,
                LD    SP,(LIST-SP)       flag that the automatic
                RES   4,(TV-FLAG)        listing has finished and
                RET                      return via CL-SET.
```

Report 5 - Out of screen

```
0C86 REPORT-5   RST   0008,ERROR-1       Call the error handling
                DEFB  +04                routine.
```

Now consider if the prompt 'scroll?' is required.

```
0C88  PO-SCR-2  DEC   (SCR-CT)           Decrease the scroll counter
                JR    NZ,0CD2,PO-SCR-3   and proceed to give the prompt
                                         only if is becomes zero.
```

Proceed to give the prompt message.

```
                LD    A,+18              The counter is reset.
                SUB   B
                LD    (SCR-CT),A
                LD    HL,(ATTR-T)        The current values of ATTR-T
                PUSH  HL                 and MASK-T are saved.
                LD    A,(P-FLAG)         The current value of P-FLAG
                PUSH  AF                 is saved.
                LD    A,+FD              Channel 'K' is opened.
                CALL  1601,CHAN-OPEN
                XOR   A                  The message 'scroll?' is
                LD    DE,+0CF8           message '0'. This message is
                CALL  0C0A,PO-MSG        now printed.
                SET   5,(TV-FLAG)        Signal 'clear the lower screen
                                         after a keystroke'.
                LD    HL,+5C3B           This is FLAGS.
                SET   3,(HL)             Signal 'L mode'.
                RES   5,(HL)             Signal 'no key yet'.
                EXX                      Note: DE should be pushed also.
                CALL  15D4,WAIT-KEY      Fetch a single key code.
                EXX                      Restore the registers.
                CP    +20                There is a jump forward to
                JR    Z,0D00,REPORT-D    REPORT-D - 'BREAK - CONT
                CP    +E2                repeats' - if the keystroke
                JR    Z,0D00,REPORT-D    was 'BREAK', 'STOP', 'N' or
                OR    +20                'n'; otherwise accept the
                CP    +6E                keystroke as indicating the
                JR    Z,0D00,REPORT-D    need to scroll the display.
                LD    A,+FE              Open channel 'S'.
                CALL  1601,CHAN-OPEN
                POP   AF                 Restore the value of
```

```
                    LD      (P-FLAG),A      P-FLAG.
                    POP     HL              Restore the values of ATTR-T
                    LD      (ATTR-T),HL     and MASK-T.
```

The display is now scrolled.

```
0CD2    PO-SCR-3    CALL    0DFE,CL-SC-ALL  The whole display is scrolled.
                    LD      B(DF-SZ)        The line and column numbers
                    INC     B               for the start of the line
                    LD      C,+21           above the lower part of the
                    PUSH    BC              display are found and saved.
                    CALL    0E9B,CL-ADDR    The corresponding attribute
                    LD      A,H             byte for this character area is
                    RRCA                    then found. The HL register pair
                    RRCA                    holds the address of the
                    RRCA                    byte.
                    AND     +03
                    OR      +58
                    LD      H,A
```

The line in question will have 'lower part' attribute values and the new line at the bottom of the display may have 'ATTR-P' values so the attribute values are exchanged.

```
                    LD      DE,+5AE0        DE points to the first attribute
                                            byte of the bottom line.
                    LD      A,(DE)          The value is fetched.
                    LD      C,(HL)          The 'lower part' value.
                    LD      B,+20           There are thirty two bytes.
                    EX      DE,HL           Exchange the pointers.
0CF0    PO-SCR-3A   LD      (DE),A          Make the first exchange
                    LD      (HL),C          and then proceed to use the
                    INC     DE              same values for the thirty
                    INC     HL              two attribute bytes of the
                    DJNZ    0CF0,PO-SCR-3A  two lines being handled.
                    POP     BC              The line and column numbers of
                                            the bottom line of the 'upper
                                            part' are fetched before
                    RET                     returning.
```

The 'scroll?' message

```
0CF8                DEFB    +80             Initial marker - stepped over.
                    DEFB    +73,+63,+72,+6F s-c-r-o
                    DEFB    +6C,+6C,+BF     l - l - ? (inverted).
```

Report 0 - BREAK - CONT repeats

```
0D00    REPORT-D    RST     0008,ERROR-1    Call the error handling
                    DEFB    +0C             routine.
```

The lower part of the display is handled as follows:

```
0D02    PO-SCR-4    CP      +02             The 'out of screen' error is
                    JR      C,0C86,REPORT-5 given if the lower part is
                    ADD     A,(DF-SZ)       going to be 'too large' and a
                    SUB     +19             return made if scrolling is
                    RET     NC              unnecessary.
                    NEG                     The A register will now hold
                                            'the number of scrolls to be
                                            made'.
                    PUSH    BC              The line and column numbers
                                            are now saved.
                    LD      B,A             The 'scroll number', ATTR-T
                    LD      HL,(ATTR-T)     MASK-T & P-FLAG are all
                    PUSH    HL              saved.
                    LD      HL,(P-FLAG)
                    PUSH    HL
                    CALL    0D40,TEMPS      The 'permanent' colour items
                                            are to be used.
```

```
                LD      A,B             The 'scroll number' is fetched.
```

The lower part of the screen is now scrolled 'A' number of times.

```
0D1C  PO-SCR-4A PUSH    AF              Save the 'number'.
                LD      HL,+5C6B        This is DF-SZ.
                LD      B,(HL)          The value in DF-SZ is
                LD      A,B             incremented; the B register
                INC     A               set to hold the former value and
                LD      (HL),A          the A register the new value.
                LD      HL,+5C89        This is S-POSN-hi.
                CP      (HL)            The jump is taken if only the
                JR      C,0D2D,PO-SCR-4B lower part of the display is
                                        to be scrolled. (B = old DF-SZ).
                INC     (HL)            Otherwise S-POSN-hi is
                LD      B,+18           incremented and the whole
                                        display scrolled. (B = +18)
0D2D  PO-SCR-4B CALL    0E00,CL-SCROLL  Scroll 'B' lines.
                POP     AF              Fetch and decrement the
                DEC     A               scroll number'.
                JR      NZ,0D1C,PO-SCR-4A Jump back until finished.
                POP     HL              Restore the value of
                LD      (P-FLAG),L      P-FLAG.
                POP     HL              Restore the values of ATTR-T
                LD      (ATTR-T),HL     and MASK-T.
                LD      BC,(S-POSN)     In case S-POSN has been
                RES     0,(TV-FLAG)     changed CL-SET is called to
                CALL    0DD9,CL-SET     give a matching value to DF-CC.
                SET     0,(TV-FLAG)     Reset the flag to indicate that
                POP     BC              the lower screen is being
                RET                     handled, fetch the line and
                                        column numbers, and then
                                        return.
```

THE 'TEMPORARY COLOUR ITEMS' SUBROUTINE

This is a most important subroutine. It is used whenever the 'permanent' details are required to be copied to the 'temporary' system variables. First ATTR-T & MASK-T are considered

```
0D4D  TEMPS     XOR     A               A is set to hold +00.
                LD      HL,(ATTR-P)     The current values of ATTR-P
                BIT     0,(TV-FLAG)     and MASK-P are fetched.
                JR      Z,0D5B,TEMPS-1  Jump forward if handing the
                                        main part of the screen.
                LD      H,A             Otherwise use +00 and the
                LD      L,(BORDCR)      value in BORDCR instead.
0D5B  TEMPS-1   LD      (ATTR-T),HL     Now set ATTR-T & MASK-T.
```

Next P-FLAG is considered.

```
                LD      HL,+5C91        This is P-FLAG.
                JR      NZ,0D65,TEMPS-2 Jump forward if dealing with
                                        the lower part of the screen
                                        (A = +00).
                LD      A,(HL)          Otherwise fetch the value of
                RRCA                    P-FLAG and move the odd bits
                                        to the even bits.
0D65  TEMPS-2   XOR     (HL)            Proceed to copy the even bits
                AND     +55             of A to P-FLAG.
                XOR     (HL)
                LD      (HL),A
                RET
```

THE 'CLS COMMAND' ROUTINE

In the first instance the whole of the display is 'cleared' - the 'pixels' are all reset and the attribute bytes are set to equal the value in ATTR-P - then the lower part of the display is reformed.

```
0D6B  CLS         CALL  0DAF,CL-ALL     The whole of the display is
                                        'cleared'.
0D6E  CLS-LOWER   LD    HL,+5C3C        This is TV-FLAG.
                  RES   5,(HL)          Signal 'do not clear the lower
                                        screen after keystroke'.
                  SET   0,(HL)          Signal 'lower part'.
                  CALL  0D4D,TEMPS      Use the permanent values. i.e.
                                        ATTR-T is copied from BORDCR.
                  LD    B,(DF-SZ)       The lower part of the screen is
                  CALL  0E44,CL-LINE    now 'cleared' with these values.
```

With the exception of the attribute bytes for lines '22' & '23' the attribute bytes for the lines in the lower part of the display will need to be made equal to ATTR-P.

```
                  LD    HL,+5AC0        Attribute byte at start of line
                                        '22'.
                  LD    A,(ATTR-P)      Fetch ATTR-P.
                  DEC   B               The line counter.
                  JR    0D8E,CLS-3      Jump forward into the loop.
0D87  CLS-1       LD    C,+20           +20 characters per line.
0D89  CLS-2       DEC   HL              Go back along the line setting
                  LD    (HL),A          the attribute bytes.
                  DEC   C
                  JR    NZ,0D89,CLS-2
0D8E  CLS-3       DJNZ  0D87,CLS-1      Loop back until finished.
```

The size of the lower part of the display can now be fixed.

```
                  LD    (DF-SZ),+02     It will be two lines in size.
```

It now remains for the following 'house keeping' tasks to be performed.

```
0D94  CL-CHAN     LD    A,+FD           Open channel 'K'.
                  CALL  1601,CHAN-OPEN
                  LD    HL,(CURCHL)     Fetch the address of the
                  LD    DE,+09F4        current channel and make
                  AND   A               the output address +09F4
0DA0  CL-CHAN-A   LD    (HL),E          (= PRINT-OUT) and the
                  INC   HL              input address +10A8
                  LD    (HL),D          (= KEY-INPUT).
                  INC   HL
                  LD    DE,+10A8
                  CCF                   First the output address
                  JR    C,0DA0,CL-CHAN-A then the input address.
                  LD    BC,+1721        As the lower part of the
                                        display is being handled the
                                        'lower print line' will be
                                        line '23'.
                  JR    0DD9,CL-SET     Return via CL-SET.
```

THE 'CLEARING THE WHOLE DISPLAY AREA' SUBROUTINE

This subroutine is called from; i. the CLS command routine. ii. the main execution routine, and iii. the automatic listing routine.

```
0DAF  CL-ALL      LD    HL,+0000        The system variable C00RDS
                  LD    (C00RDS),HL     is reset to zero.
                  RES   0,(FLAGS2)      Signal 'the screen is clear'.
                  CALL 0D94,CL-CHAN     Perform the 'house keeping'
                                        tasks.
                  LD    A,+FE           Open channel 'S'.
                  CALL  1601,CHAN-OPEN
                  CALL  0D4D,TEMPS      Use the 'permanent' values.
                  LD    B,+18           Now 'clear' the 24 lines
                  CALL  0E44,CL-LINE    of the display.
                  LD    HL,(CURCHL)     Ensure that the current
                  LD    DE,+09F4        output address is +09F4
```

```
                LD      (HL),E          (PRINT-OUT).
                INC     HL
                LD      (HL),D
                LD      (SCR-CT),+01    Reset the scroll counter.
                LD      BC,+1821        As the upper part of the display
                                        is being handled the 'upper print
                                        line' will be Line '0'.
                                        Continue into CL-SET.
```

THE 'CL-SET' SUBROUTINE

This subroutine is entered with the BC register pair holding the line and column numbers of a character areas, or the C register holding the column number within the printer buffer. The appropriate address of the first character bit is then found. The subroutine returns via PO-STORE so as to store all the values in the required system variables.

```
0DD9    CL-SET      LD      HL,+5B00        The start of the printer buffer.
                    BIT     1,(FLAGS)       Jump forward if handling the
                    JR      NZ,0DF4,CL-SET-2 printer buffer.
                    LD      A,B             Transfer the line number.
                    BIT     0,(TV-FLAG)     Jump forward if handling the
                    JR      Z,0DEE,CL-SET-1 main part of the display.
                    ADD     A,(DF-SZ)       The top line of the lower
                    SUB     +18             part of the display is called
                                            'line +18' and this has to be
                                            converted.
0DEE    CL-SET-1    PUSH    BC              The line & column numbers are
                                            saved.
                    LD      B,A             The line number is moved.
                    CALL    0E9B,CL-ADDR    The address for the start of the
                                            line is formed in HL.
                    POP     BC              The line & column numbers are
                                            fetched back.
0DF4    CL-SET-2    LD      A,+21           The column number is now
                    SUB     C               reversed and transferred to
                    LD      E,A             the DE register pair.
                    LD      D,+00
                    ADD     HL,DE           The required address is now
                    JP      0ADC,PO-STORE   formed; and the address and
                                            the line and column numbers
                                            are stored by jumping to
                                            PO-STORE.
```

THE 'SCROLLING' SUBROUTINE

The number of lines of the display that are to be scrolled has to be held on entry to the main subroutine in the B register.

```
0DFE    CL-SC-ALL   LD      B,+17           The entry point after 'scroll?'
```

The main entry point - from above and when scrolling for INPUT..AT.

```
0E00    CL-SCROLL   CALL    0E9B,CL-ADDR    Find the starting address of
                                            the line.
                    LD      C,+08           There are eight pixel lines to
                                            a complete line.
```

Now enter the main scrolling loop. The B register holds the number of the top line to be scrolled, the HL register pair the starting address in the display area of this line and the C register the pixel line counter.

```
0E05    CL-SCR-1    PUSH    BC              Save both counters.
                    PUSH    HL              Save the starting address.
                    LD      A,B             Jump forward unless
                    AND     +07             dealing at the present
                    LD      A,B             moment with a 'third' of
                    JR      NZ,0E19,CL-SCR-3 the display.
```

The pixel lines of the top lines of the 'thirds' of the display have to be moved across the 2K boundaries. (Each 'third' = 2K.)

```
0E0D    CL-SCR-2    EX      DE,HL           The result of this
                    LD      HL,+F8E0        manipulation is to leave HL
                    ADD     HL,DE           unchanged and DE pointing to
                    EX      DE,HL           the required destination.
                    LD      BC,+0020        There are +20 characters.
                    DEC     A               Decrease the counter as one line
                                            is being dealt with.
                    LDIR                    Now move the thirty two bytes.
```

The pixel lines within the 'thirds' can now be scrolled. The A register holds, on the first pass, +01 - +07, +09 - +0F or +11 - +17.

```
0E19    CL-SCR-3    EX      DE,HL           Again DE is made to point
                    LD      HL,+FFE0        to the required destination.
                    ADD     HL,DE           This time only thirty two
                    EX      DE,HL           locations away.
                    LD      B,A             Save the line number in B.
                    AND     +07             Now find how many characters
                    RRCA                    there are remaining in the
                    RRCA                    'third'.
                    RRCA
                    LD      C,A             Pass the 'character total' to the
                                            C register.
                    LD      A,B             Fetch the line number.
                    LD      B,+00           BC holds the 'character total'
                    LDIR                    and a pixel line from each of the
                                            characters is 'scrolled'.
                    LD      B,+07           Now prepare to increment the
                                            address to jump across a 'third'
                                            boundary.
                    ADD     HL,BC           Increase HL by +0700.
                    AND     +F8             Jump back if there are any
                    JR      NZ,0E0D,CL-SCR-2 'thirds' left to consider.
```

Now find if the loop has been used eight times - once for each pixel line.

```
                    POP     HL              Fetch the original address.
                    INC     H               Address the next pixel line.
                    POP     BC              Fetch the counters.
                    DEC     C               Decrease the pixel line counter
                    JR      NZ,0E05,CL-SR-1 and jump back unless eight lines
                                            have been moved.
```

Next the attribute bytes are scrolled. Note that the B register still holds the number of lines to be scrolled and the C register holds zero.

```
                    CALL    0E88,CL-ATTR    The required address in the
                                            attribute area and the number
                                            of characters in 'B' lines are
                                            found.
                    LD      HL,+FFE0        The displacement for all
                    ADD     HL,DE           the attribute bytes is
                    EX      DE,HL           thirty two locations away.
                    LDIR                    The attribute bytes are
                                            'scrolled'.
```

It remains now to clear the bottom line of the display.

```
                    LD      B,+01           The B register is loaded with
                                            +01 and CL-LINE is entered.
```

THE 'CLEAR LINES' SUBROUTINE

This subroutine will clear the bottom 'B' lines of the display.

```
0E44    CL-LINE     PUSH    BC              The line number is saved for the
                                            duration of the subroutine.
                    CALL    0E9B,CL-ADDR    The starting address for the line
                                            is formed in HL.
```

```
                    LD      C,+08           Again there are eight pixel
                                            lines to be considered.
```

Now enter a loop to clear all the pixel lines.

```
0E4A    CL-LINE-1   PUSH    BC              Save the line number and the
                                            pixel line counter.
                    PUSH    HL              Save the address.
                    LD      A,B             Save the line number in A.
0E4D    CL-LINE-2   AND     +07             Find how many characters are
                    RRCA                    involved in 'B mod 8' lines.
                    RRCA                    Pass the result to the
                    RRCA                    C register. (C will hold +00
                    LD      C,A             i.e. 256 dec. for a 'third'.)
                    LD      A,B             Fetch the line number.
                    LD      B,+00           Make the BC register pair
                    DEC     C               hold 'one less' than the number
                                            of characters.
                    LD      D,H             Make DE point to the first
                    LD      E,L             character.
                    LD      (HL),+00        Clear the pixel-byte of the
                                            first character.
                    INC     DE              Make DE point to the second
                    LDIR                    character and then clear the
                                            pixel-bytes of all the other
                                            characters.
                    LD      DE,+0701        For each 'third' of the
                    ADD     HL,DE           display HL has to be increased
                                            by +0701.
                    DEC     A               Now decrease the line number.
                    AND     +F8             Discard any extra lines and
                    LD      B,A             pass the 'third' count to B.
                    JR      NZ,0E4D,CL-LINE-2  Jump back if there are still
                                            'thirds' to be dealt with.
```

Now find if the loop has been used eight times.

```
                    POP     HL              Update the address for each
                    INC     H               pixel line.
                    POP     BC              Fetch the counters.
                    DEC     C               Decrease the pixel line
                    JR      NZ,0E4A,CL-LINE-1  counter and jump back unless
                                            finished.
```

Next the attribute bytes are set as required. The value in ATTR-P will be used when handling the main part of the display and the value in BORDCR when handling the lower part.

```
                    CALL    0E88,CL-ATTR    The address of the first
                                            attribute byte and the number
                                            of bytes are found.
                    LD      H,D             HL will point to the first
                    LD      L,E             attribute byte and DE the
                    INC     DE              second.
                    LD      A,(ATTR-P)      Fetch the value in ATTR-P.
                    BIT     0,(TV-FLAG)     Jump forward if handling the
                    JR      Z,0E80,CL-LINE-3  main part of the screen.
                    LD      A,(BORDCR)      Otherwise use BORDCR instead.
0E80    CL-LINE-3   LD      (HL),A          Set the attribute byte.
                    DEC     BC              One byte has been done.
                    LDIR                    Now copy the value to all the
                                            attribute bytes.
                    POP     BC              Restore the line number.
                    LD      C,+21           Set the column number to the
                    RET                     lefthand column and return.
```

THE 'CL-ATTR' SUBROUTINE

This subroutine has two separate functions.

i. For a given display area address the appropriate attribute address is returned in the DE register pair. Note that the value on entry points to the 'ninth' line of a character.

ii. For a given line number, in the B register, the number of character areas in the display from the start of that line onwards is returned in the BC register pair.

```
0E88    CL-ATTR     LD      A,H         Fetch the high byte.
                    RRCA                Multiply this value by
                    RRCA                thirty two.
                    RRCA
                    DEC     A           Go back to the 'eight' line.
                    OR      +50         Address the attribute area.
                    LD      H,A         Restore to the high byte and
                    EX      DE,HL       transfer the address to DE.
                    LD      H,C         This is always zero.
                    LD      L,B         The line number.
                    ADD     HL,HL       Multiply by thirty two.
                    ADD     HL,HL
                    ADD     HL,HL
                    ADD     HL,HL
                    ADD     HL,HL
                    LD      B,H         Move the result to the
                    LD      C,L         BC register pair before
                    RET                 returning.
```

THE 'CL-ADDR' SUBROUTINE

For a given line number, in the B register, the appropriate display file address is formed in the HL register pair.

```
0E9B    CL-ADDR     LD      A,+18       The line number has to be
                    SUB     B           reversed.
                    LD      D,A         The result is saved in D.
                    RRCA                In effect '(A mod 8) * 32'.
                    RRCA                In a 'third' of the display
                    RRCA                the low byte for the:
                    AND     +E0         1st. line = +00,
                                        2nd. line = +20, etc.
                    LD      L,A         The low byte goes into L.
                    LD      A,D         The true line number is fetched.
                    AND     +18         In effect '64 +8 * INT (A/8)'
                    OR      +40         For the upper 'third' of the
                                        display the high byte = +40,
                                        middle 'third' = +48, and the
                                        lower 'third' = +50.
                    LD      H,A         The high byte goes to H.
                    RET                 Finished.
```

THE 'COPY' COMMAND ROUTINE

The one hundred and seventy six pixel lines of the display are dealt with one by one.

```
0EAC    COPY        DI                  The maskable interrupt is
                                        disabled during COPY.
                    LD      B,+B0       The '176' lines.
                    LD      HL,+4000    The base address of the display.
```

The following loop is now entered.

```
0EB2    COPY-1      PUSH    HL          Save the base address and
                    PUSH    BC          the number of the line.
                    CALL    0EF4,COPY-LINE  It is called '176' times.
                    POP     BC          Fetch the line number and
                    POP     HL          the base address.
                    INC     H           The base address is updated by
                                        '256' locations for each line of
                                        pixels.
```

```
                    LD      A,H             Jump forward and hence round
                    AND     +07             the loop again directly for the
                    JR      NZ,0EC9,COPY-2  eight pixel lines of a character
                                            line.
```

For each new line of characters the base address has to be updated.

```
                    LD      A,L             Fetch the low byte.
                    ADD     A,+20           Update it by +20 bytes.
                    LD      L,A             The carry flag will be reset when
                                            'within thirds' of the display.
                    CCF                     Change the carry flag.
                    SBC     A,A             The A register will hold +F8
                    AND     +F8             when within a 'third' but +00
                                            when a new third' is reached.
                    ADD     A,H             The high byte of the
                    LD      H,A             address is now updated.
0EC9    COPY-2      DJNZ    0EB2,COPY-1     Jump back until '176' lines have
                                            been printed.
                    JR      0EDA,COPY-END   Jump forward to the end
                                            routine.
```

THE 'COPY-BUFF' SUBROUTINE

This subroutine is called whenever the printer buffer is to have its contents passed to the printer.

```
0ECD    COPY-BUFF   DI                      Disable the maskable interrupt.
                    LD      HL,+5800        The base address of the printer
                                            buffer.
                    LD      B,+08           There are eight pixel lines.
0ED3    COPY-3      PUSH    BC              Save the line number.
                    CALL    0EF4,COPY-LINE  It is called '8' times.
                    POP     BC              Fetch the line number.
                    DJNZ    0ED3,COPY-3     Jump back until '8' lines
                                            have been printed.
```

Continue into the COPY-END routine.

```
0EDA    COPY-END    LD      A,+04           Stop the printer motor.
                    OUT     (+FB),A
                    EI                      Enable the maskable interrupt
                                            and continue into CLEAR-PRB.
```

THE 'CLEAR PRINTER BUFFER' SUBROUTINE

The printer buffer is cleared by calling this subroutine.

```
0EDF    CLEAR-PRB   LD      HL,+5B00        The base address of the printer
                                            buffer.
                    LD      (PR-CC-lo),L    Reset the printer 'column'.
                    XOR     A               Clear the A register.
                    LD      B,A             Also clear the B register in
                                            effect B holds dec.256).
0EE7    PRB-BYTES   LD      (HL),A          The '256' bytes of the
                    INC     HL              printer buffer are all
                    DJNZ    0EE7,PRB-BYTES  cleared in turn.
                    RES     1,(FLAGS2)      Signal 'the buffer is empty'.
                    LD      C,+21           Set the printer position and
                    JP      0DD9,CL-SET     return via CL-SET & P0-STORE.
```

THE 'COPY-LINE' SUBROUTINE

The subroutine is entered with the HL register pair holding the base address of the thirty two bytes that form the pixel-line and the B register holding the pixel-line number.

```
0EF4    COPY-LINE   LD      A,B             Copy the pixel-line number.
                    CP      +03             The A register will hold
                    SBC     A,A             +00 until the last two lines
                    AND     +02             are being handled.
```

```
                OUT     (+FB),A         Slow the motor for the last two
                                        pixel lines only.
                LD      D,A             The D register will hold either
                                        +00 or +02.
```

There are three tests to be made before doing any 'printing'.

```
0EFD  COPY-L-1  CALL    1F54,BREAK-KEY  Jump forward unless the
                JR      C,0F0C,COPY-L-2 BREAK key is being pressed.
                LD      A,+04           But if it is then;
                OUT     (+FB),A         stop the motor,
                EI                      enable the maskable interrupt,
                CALL    0EDF,CLEAR-PRB  clear the printer buffer and exit
                RST     0008,ERROR-1    via the error handling routine
                DEFB    +0C             - 'BREAK-CONT repeats'.
0F0C  COPY-L-2  IN      A,(+FB)         Fetch the status of the
                ADD     A,A             printer.
                RET     M               Make an immediate return if the
                                        printer is not present.
                JR      NC,0EFD,COPY-L-1 Wait for the stylus.
                LD      C,+20           There are thirty two bytes.
```

Now enter a loop to handle these bytes.

```
0F14  COPY-L-3  LD      E,(HL)          Fetch a byte.
                INC     HL              Update the pointer.
                LD      B,+08           Eight bits per byte.
0F18  COPY-L-4  RL      D               Move D left.
                RL      E               Move each bit into the carry.
                RR      D               Move D back again, picking up
                                        the carry from E.
0F1E  COPY-L-5  IN      A,(+FB)         Again fetch the status of the
                RRA                     printer and wait for the
                JR      NC,0F1E,COPY-L-5 signal from the encoder.
                LD      A,D             Now go ahead and pass the
                OUT     (+FB),A         'bit' to the printer
                                        Note: bit 2 - low starts the
                                        motor, bit 1 - high slows the
                                        motor and bit 7 is high for the
                                        actual 'printing'.
                DJNZ    0F18,COPY-L-4   'Print' each bit.
                DEC     C               Decrease the byte counter.
                JR      NZ,0F14,COPY-L-3 Jump back whilst there are
                RET                     still bytes; otherwise return.
```

THE 'EDITOR' ROUTINES

The editor is called on two occasions:
i. From the main execution routine so that the user can enter a BASIC line into the system.

ii. From the INPUT command routine.

First the 'error stack pointer' is saved and an alternative address provided.

```
0F2C  EDITOR    LD      HL,(ERR-SP)     The current value is saved on
                PUSH    HL              the machine stack.
0F30  ED-AGAIN  LD      HL,+107F        This is ED-ERROR.
                PUSH    HL              Any event that leads to the
                LD      (ERR-SP),SP     error handling routine being
                                        used will come back to
                                        ED-ERROR.
```

A loop is now entered to handle each keystroke.

```
0F38  ED-LOOP   CALL    15D4,WAIT-KEY   Return once a key has been
                                        pressed.
                PUSH    AF              Save the code temporarily.
```

```
                LD      D,+00           Fetch the duration of the
                LD      E,(PIP)         keyboard click.
                LD      HL,+00C8        And the pitch.
                CALL    03B5,BEEPER     Now make the 'pip'.
                POP     AF              Restore the code.
                LD      HL,+0F38        Pre-load the machine stack
                PUSH    HL              with the address of ED-LOOP.
```

Now analyse the code obtained.

```
                CP      +18             Accept all character codes,
                JR      NC,0F81,ADD-CHAR graphic codes and tokens.
                CP      +07             Also accept ','.
                JR      C,0F81,ADD-CHAR
                CP      +10             Jump forward if the code
                JR      C,0F92,ED-KEYS  represents an editing key.
```

The control keys - INK to TAB -are now considered.

```
                LD      BC,+0002        INK & PAPER will require
                                        two locations.
                LD      D,A             Copy the code to 0.
                CP      +16             Jump forward with INK &
                JR      C,0F6C,ED-CONTR PAPER'
```

AT & TAB would be handled as follows:

```
                INC     BC              Three locations required.
                BIT     7,(FLAGX)       Jump forward unless dealing
                JP      Z,101E,ED-IGNORE with INPUT LINE... .
                CALL    15D4,WAIT-KEY   Get the second code.
                LD      E,A             and put it in E.
```

The other bytes for the control characters are now fetched.

```
0F6C    ED-CONTR CALL   15D4,WAIT-KEY   Get another code.
                PUSH    DE              Save the previous codes.
                LD      HL,(K-CUR)      Fetch K-CUR.
                RES     0,(MODE)        Signal 'K mode'.
                CALL    1655,MAKE-ROOM  Make two or three spaces.
                POP     BC              Restore the previous codes.
                INC     HL              Point to the first location.
                LD      (HL),B          Enter first code.
                INC     HL              Then enter the second code
                LD      (HL),C          which will be Overwritten if
                                        there are only two codes - i.e.
                                        with INK & PAPER.
                JR      0F8B,ADD-CH-1   Jump forward.
```

THE 'ADDCHAR' SUBROUTINE
This subroutine actually adds a code to the current EDIT or INPUT line.

```
0F81    ADD-CHAR RES    0,(MODE)        Signal 'K mode'.
                LD      HL,(K-CUR)      Fetch the cursor position.
                CALL    1652,ONE-SPACE  Make a single space.
0F8B    ADD-CH-1 LD     (DE),A          Enter the code into the space
                INC     DE              and signal that the cursor is to
                LD      (K-CUR),DE      occur at the location after. Then
                RET                     return indirectly to ED-LOOP.
```

The editing keys are dealt with as follows:

```
0F92    ED-KEYS LD      E,A             The code is transferred to
                LD      C,+00           the DE register pair.
                LD      HL,+0F99        The base address of the editing
                                        key table.
                ADD     HL,DE           The entry is addressed and
                LD      E,(HL)          then fetched into E.
                ADD     HL,DE           The address of the handling
```

```
                PUSH    HL              routine is saved on the machine
                                        stack.
                LD      HL,(K-CUR)      The HL register pair is set and
                RET                     an indirect jump made to the
                                        required routine.
```

THE 'EDITING KEYS' TABLE

address	offset	character	address	offset	character
0FA0	09	EDIT	0FA5	70	DELETE
0FA1	66	cursor left	0FA6	7E	ENTER
0FA2	6A	cursor right	0FA7	CF	SYMBOL SHIFT
0FA3	50	cursor down	0FA8	D4	GRAPHICS
0FA4	85	cursor up			

THE 'EDIT KEY' SUBROUTINE

When in 'editing mode' pressing the EDIT key will bring down the 'current BASIC line'. However in 'INPUT mode' the action of the EDIT key is to clear the current reply and allow a fresh one.

```
0FA9    ED-EDIT LD      HL,(E-PPC)      Fetch the current line number.
                BIT     5,(FLAGX)       But jump forward if in
                JP      NZ,1097,CLEAR-SP 'INPUT mode'.
                CALL    196E,LINE-ADDR  Find the address of the start of
                CALL    1695,LINE-NO    the current line and hence its
                                        number.
                LD      A,D             If the line number returned is
                OR      E               zero then simply clear the
                JP      Z,1097,CLEAR-SP editing area.
                PUSH    HL              Save the address of the line.
                INC     HL              Move on to collect the
                LD      C,(HL)          length of the line.
                INC     HL
                LD      B,(HL)
                LD      HL,+000A        Add +0A to the length and test
                ADD     HL,BC           that there is sufficient room
                LD      B,H             for a copy of the line.
                LD      C,L
                CALL    1F05,TEST-ROOM
                CALL    1097,CLEAR-SP   Now clear the editing area.
                LD      HL,(CURCHL)     Fetch the current channel
                EX      (SP),HL         address and exchange it for the
                                        address of the line.
                PUSH    HL              Save it temporarily.
                LD      A,+FF           Open channel 'A' so that the
                CALL    1601,CHAN-OPEN  line will be copied to the editing
                                        area.
                POP     HL              Fetch the address of the line.
                DEC     HL              Goto before the line.
                DEC     (E-PPC-lo)      Decrement the current line
                                        number so as to avoid
                                        printing the cursor.
                CALL    1855,OUT-LINE   Print the BASIC line
                INC     (E-PPC-lo)      Increment the current line
                                        number.
                                        Note: The decrementing of the
                                        line number does not always
                                        stop the cursor from being
                                        printed.
                LD      HL,(E-LINE)     Fetch the start of the line in
                INC     HL              the editing area and step past
                INC     HL              the line number and the
                INC     HL              length to find the address
                INC     HL              for K-CUR.
```

```
                LD      (K-CUR),HL
                POP     HL              Fetch the former channel
                CALL    1615,CHAN-FLAG  address and set the
                RET                     appropriate flags before
                                        returning to ED-LOOP.
```

THE 'CURSOR DOWN EDITING' SUBROUTINE

```
0FF3  ED-DOWN   BIT     5,(FLAGX)       Jump forward if in
                JR      NZ,1001,ED-STOP 'INPUT' mode'.
                LD      HL,+5C49        This is E-PPC.
                CALL    190F,LN-FETCH   The next line number is found
                JR      106E,ED-LIST    and a new automatic listing
                                        produced.
1001  ED-STOP   LD      (ERR-NR),+10    'STOP in INPUT' report.
                JR      1024,ED-ENTER   Jump forward.
```

THE 'CURSOR LEFT EDITING' SUBROUTINE

```
1007  ED-LEFT   CALL    1031,ED-EDGE    The cursor is moved.
                JR      1011,ED-CUR     Jump forward.
```

THE 'CURSOR RIGHT EDITING' SUBROUTINE

```
100C  ED-RIGHT  LD      A,(HL)          The current character is tested
                CP      +0D             and if it is 'carriage return'
                RET     Z               then return.
                INC     HL              Otherwise make the cursor
                                        come after the character.
1011  ED-CUR    LD      (K-CUR),HL      Set the system variable K-CUR.
                RET
```

THE 'DELETE EDITING' SUBROUTINE

```
1015  ED-DELETE CALL    1031,ED-EDGE    Move the cursor leftwards.
                LD      BC,+0001        Reclaim the current
                JP      19E8,RECLAIM-2  character.
```

THE 'ED-IGNORE' SUBROUTINE

```
101E  ED-IGNORE CALL    15D4,WAIT-KEY   The next two codes from the
                CALL    15D4,WAIT-KEY   key-input routine are ignored.
```

THE 'ENTER EDITING' SUBROUTINE

```
1024  ED-ENTER  POP     HL              The address of ED-LOOP and
                POP     HL              ED-ERROR are discarded.
1026  ED-END    POP     HL              The old value of ERR-SP
                LD      (ERR-SP),HL     is restored.
                BIT     7,(ERR-NR)      Now return if there were
                RET     NZ              no errors.
                LD      SP,HL           Otherwise make an indirect
                RET                     jump to the error routine.
```

THE 'ED-EDGE' SUBROUTINE

The address of the cursor is in the HL register pair and will be decremented unless the cursor is already at the start of the line. Care is taken not to put the cursor between control characters and their parameters.

```
1031  ED-EDGE   SCF                     DE will hold either E-LINE
                CALL    1195,SET-DE     (for editing) or WORKSP
                                        (for INPUTing).
                SBC     HL,DE           The carry flag will become set
                                        if the cursor is already to be at
                ADD     HL,DE           the start of the line.
                INC     HL              Correct for the subtraction.
```

```
                POP     BC              Drop the return address.
                RET     C               Return via ED-LOOP if the
                                        carry flag is set.
                PUSH    BC              Restore the return address.
                LD      B,H             Move the current address of
                LD      C,L             the cursor to BC.
```

Now enter a loop to check that control characters are not split from their parameters.

```
103E  ED-EDGE-1 LD      H,D             HL will point to the
                LD      L,E             character in the line after
                INC     HL              that addressed by DE.
                LD      A,(DE)          Fetch a character code.
                AND     +F0             Jump forward if the code
                CP      +10             does not represent
                JR      NZ,1051,ED-EDGE-2 INK to TAB.
                INC     HL              Allow for one parameter.
                LD      A,(DE)          Fetch the code anew.
                SUB     +17             Carry is reset for TAB.
                ADC     A,+00           Note: This splits off AT & TAB
                                        but AT & TAB in this form are
                                        not implemented anyway so it
                                        makes no difference.
                JR      NZ,1051,ED-EDGE-2 Jump forward unless dealing
                INC     HL              with AT & TAB which would
                                        have two parameters, if used.
1051  ED-EDGE-2 AND     A               Prepare for true subtraction.
                SBC     HL,BC           The carry flag will be reset
                ADD     HL,BC           when the 'updated pointer'
                                        reaches K-CUR.
                EX      DE,HL           For the next loop use the
                JR      C,103E,ED-EDGE-1 'updated pointer', but if
                RET                     exiting use the 'present
                                        pointer' for K-CUR.
                                        Note: It is the control character
                                        that is deleted when using
                                        DELETE.
```

THE 'CURSOR UP EDITING' SUBROUTINE

```
1059  ED-UP     BIT     5,(FLAGX)       Return if in 'INPUT mode'.
                RET     NZ
                LD      HL,(E-PPC)      Fetch the current line
                CALL    196E,LINE-ADDR  number and its start address.
                EX      DE,HL           HL now points to the previous
                                        line.
                CALL    1695,LINE-NO    This line's number is fetched.
                LD      HL,+5C4A        This is E-PPC-hi.
                CALL    1910,LN-STORE   The line number is stored.
106E  ED-LIST   CALL    1795,AUTO-LIST  A new automatic listing is
                LD      A,+00           now produced and channel 'K'
                JP      1601,CHAN-OPEN  re-opened before returning to
                                        ED-LOOP.
```

THE 'ED-SYMBOL' SUBROUTINE

If SYMBOL & GRAPHICS codes were used they would be handled as follows:

```
1076  ED-SYMBOL BIT     7,(FLAGX)       Jump back unless dealing with
                JR      Z,1024,ED-ENTER INPUT. LINE.
107C  ED-GRAPH  JP      0F81,ADD-CHAR   Jump back.
```

THE 'ED-ERROR' SUBROUTINE

Come here when there has been some kind of error.

```
107F  ED-ERROR  BIT     4,(FLAGS2)      Jump back if using other than
                JR      Z,1026,ED-END   channel 'K'.
```

```
                LD      (ERR-NR),+FF    Cancel the error number and
                LD      D,+00           give a 'rasp' before going
                LD      E,(RASP)        around the editor again.
                LD      HL,+1A90
                CALL    0385,BEEPER
                JP      0F30,ED-AGAIN
```

THE 'CLEAR-SP' SUBROUTINE

The editing area or the work space is cleared as directed.

```
1097    CLEAR-SP    PUSH    HL              Save the pointer to the space.
                    CALL    1190,SET-HL     DE will point to the first
                                            character and HL the last.
                    DEC     HL              The correct amount is now
                    CALL    19E5,RECLAIM-1  reclaimed.
                    LD      (K-CUR),HL      The system variables K-CUR
                    LD      (MODE),+00      and MODE ('K mode') are
                    POP     HL              initialised before fetching
                    RET                     the pointer and returning.
```

THE 'KEYBOARD INPUT' SUBROUTINE

This important subroutine returns the code of the last key to have bean pressed but note that CAPS LOCK, the changing of the mode and the colour control parameters are handled within the subroutine.

```
10A8    KEY-INPUT   BIT     3,(TV-FLAG)     Copy the edit-linear the
                    CALL    NZ,111D,ED-COPY INPUT-line to the screen if
                                            the mode has changed.
                    AND     A               Return with both carry
                    BIT     5,(FLAGS)       and zero flags reset if no
                    RET     Z               new key has been pressed
                    LD      A,(LAST-K)      Otherwise fetch the code and
                    RES     5,(FLAGS)       signal that it has been taken
                    PUSH    AF              Save the code temporarily.
                    BIT     5,(TV-FLAG)     Clear the lower part of the
                    CALL    NZ,0D6E,CLS-LOWER display if necessary;
                                            e.g. after 'scroll?';
                    POP     AF              Fetch the code.
                    CP      +20             Accept all characters and
                    JR      NC,111B,KEY-DONE token codes.
                    CP      +10             Jump forward with most of
                    JR      NC,10FA,KEY-CONTR the control character codes.
                    CP      +06             Jump forward with the 'mode'.
                    JR      NC,10DB,KEY=M&CL codes and the CAPS LOCK code.
```

Now deal with the FLASH, BRIGHT& INVERSE codes.

```
                    LD      B,A             Save the code.
                    AND     +01             Keep only bit 0.
                    LD      C,A             C holds +00 (= OFF) or
                                            C holds +01 (= ON).
                    LD      A,B             Fetch the code.
                    RRA                     Rotate it once (losing bit 0).
                    ADD     A,+12           Increase it by +12 giving for
                    JR      1105,KEY-DATA   FLASH - +12, BRIGHT - +13
                                            and INVERSE - +14.
```

The CAPS LOCK code and the mode codes are dealt with 'locally'.

```
10DB    KEY-M&CL    JR      NZ,10E6,KEY-MODE Jump forward with 'mode' codes.
                    LD      HL,+5C6A        This is FLAGS2.
                    LD      A,+08           Flip bit 3 of FLAGS2. This is
                    XOR     (HL)            the CAPS LOCK flag.
                    LD      (HL),A
                    JR      10F4,KEY-FLAG   Jump forward.
10E6    KEY-MODE    CP      +0E             Check the lower limit.
```

```
                    RET         C
                    SUB         +0D             Reduce the range.
                    LD          HL,+5C41        This is MODE.
                    CP          (HL)            Has it been changed?
                    LD          (HL),A          Enter the new 'mode' code.
                    JR          NZ,10F4,KEY-FLAG Jump if it has changed;
                    LD          (HL),+00        otherwise make it 'L mode'.
10F4    KEY-FLAG    SET 3,(TV-FLAG)             Signal 'the mode might have
                                                changed.
                    CP          A               Reset the carry flag and
                    RET                         return.
```

The control key codes (apart from FLASH, BRIGHT & INVERSE) are manipulated.

```
10FA    KEY-CONTR   LD          B,A             Save the code.
                    AND         +07             Make the C register hold the
                    LD          C,A             parameter. (+00 to +07)
                    LD          A,+10           A now holds the INK code.
                    BIT         3,B             But if the code was an
                    JR          NZ,1105,KEY-DATA 'unshifted' code then make A
                    INC         A               hold the PAPER code.
```

The parameter is saved in K-DATA and the channel address changed from KEY-INPUT to KEY-NEXT.

```
1105    KEY-DATA    LD          (K-DATA),C      Save the parameter.
                    LD          DE,+110D        This is KEY-NEXT.
                    JR          1113,KEY-CHAN   Jump forward.
```

Note: On the first pass entering at KEY-INPUT the A register is returned holding a control code' and then on the next pass, entering at KEY-NEXT, it is the parameter that is returned.

```
110D    KEY-NEXT    LD          A,(K-DATA)      Fetch the parameter.
                    LD          DE,+10A8        This is KEY-INPUT.
```

Now set the input address in the first channel area.

```
1113    KEY-CHAN    LD          HL,(CHANS)      Fetch the channel address.
                    INC         HL
                    INC         HL
                    LD          (HL),E          Now set the input address.
                    INC         HL
                    LD          (HL),D
```

Finally exit with the required code in the A register.

```
111B    KEY-DONE    SCF                         Show a code has been found
                    RET                         and return.
```

THE 'LOWER SCREEN COPYING' SUBROUTINE

This subroutine is called whenever the line in the editing area or the INPUT area is to be printed in the lower part of the screen.

```
111D    ED-COPY     CALL        0D4D,TEMPS      Use the permanent colours.
                    RES         3,(TV-FLAG)     Signal that the 'mode is to be
                    RES         5,(TV-FLAG)     considered unchanged' and the
                                                'lower screen does not need
                                                clearing'.
                    LD          HL,(S-POSNL)    Save the current value of
                    PUSH        HL              S-POSNL.
                    LD          HL,(ERR-SP)     Keep the current value of
                    PUSH        HL              ERR-SP.
                    LD          HL,+1167        This is ED-FULL.
                    PUSH        HL              Push this address on to the
                    LD          (ERR-SP),SP     machine stack to make ED-FULL
                                                the entry point following an
                                                error.
```

```
                LD      HL,(ECHO-E)     Push the value of ECHO-E
                PUSH    HL              on to the stack.
                SCF                     Make HL point to the start
                CALL    1195,SET-HL     of the space and DE the end.
                EX      DE,HL
                CALL    187D,OUT-LINE2  Now print the line.
                EX      DE,HL           Exchange the pointers and
                CALL    18E1,OUT-CURS   print the cursor.
                LD      HL,(S-POSNL)    Next fetch the Current value
                EX      (SP),HL         of S-POSNL and exchange it
                                        with ECHO-E.
                EX      DE,HL           Pass ECHO-E to DE.
                CALL    0D4D,TEMPS      Again fetch the permanent
                                        colours.
```

The remainder of any line that has been started is now completed with spaces printed with the 'permanent' PAPER colour.

```
1150    ED-BLANK    LD      A,(S-POSNL-hi)      Fetch the current line number
                    SUB     D                   and subtract the old line number.
                    JR      C,117C,ED-C-DONE    Jump forward if no 'blanking'
                                                of lines required.
                    JR      NZ,115E,ED-SPACES   Jump forward if not on the
                                                same line.
                    LD      A,E                 Fetch the old column number
                    SUB     (S-POSNL-lo)        and subtract the new column
                                                number.
                    JR      NC,117C,ED-C-DONE   Jump if no spaces required.
115E    ED-SPACES   LD      A,+20               A 'space'.
                    PUSH    DE                  Save the old values,
                    CALL    09F4,PRINT-OUT      Print it.
                    POP     DE                  Fetch the old values.
                    JR      1150,ED-BLANK       Back again.
```

New deal with any errors.

```
1167    ED-FULL     LD      D,+00               Give out a 'rasp'.
                    LD      E,(RASP)
                    LD      HL,+1A90
                    CALL    03B5,BEEPER
                    LD      (ERR-NR),+FF        Cancel the error number.
                    LD      DE,(S-POSNL)        Fetch the current value of
                    JR      117E,ED-C-END       S-POSNL and jump forward.
```

The normal exit upon completion of the copying over of the editor the INPUT line.

```
117C    ED-C-DONE   POP     DE                  The new position value.
                    POP     HL                  The 'error address'.
```

But come here after an error.

```
117E    ED-C-END    POP     HL                  The old value of ERR-SP is
                    LD      (ERR-SP),HL         restored.
                    POP     BC                  Fetch the old value of
                                                S-POSNL.
                    PUSH    DE                  Save the new position values.
                    CALL    0DD9,CL-SET         Set the system variables.
                    POP     HL                  The old value of S-POSNL
                    LD      (ECHO-E),HL         goes into ECHO-E.
                    LD      (X-PTR-hi),+00      X-PTR is cleared in a
                    RET                         suitable manner and the return
                                                Made.
```

THE 'SET-HL' AND 'SET-DE' SUBROUTINES

These subroutines return with HL pointing to the first location and DE the 'last' location of either the editing area or the work space.

```
1190    SET-HL      LD      HL,(WORKSP)         Point to the last location
```

```
                DEC     HL              of the editing area.
                AND     A               Clear the carry flag.
1195    SET-DE  LD      DE,(E-LINE)     Point to the start of the
                BIT     5,(FLAGX)       editing area and return if
                RET     Z               in 'editing mode'.
                LD      DE,(WORKSP)     Otherwise change DE.
                RET     C               Return if now intended.
                LD      HL,(STKBOT)     Fetch STKBOT and then
                RET                     return.
```

THE 'REMOVE-FP' SUBROUTINE

This subroutine removes the hidden floating-point forms in a BASIC line.

```
11A7    REMOVE-FP LD    A,(HL)          Each character in turn is
                                        examined.
                CP      +0E             Is it a number marker?
                LD      BC,+0006        It will occupy six locations.
                CALL    Z,19E8,RECLAIM-2 Reclaim the F-P number.
                LD      A,(HL)          Fetch the code again.
                INC     HL              Update the pointer.
                CP      +0D             'Carriage return'?
                JR      NZ,11A7,REMOVE-FP Back if not. But make a
                RET                     simple return if it is.
```

THE EXECUTIVE ROUTINES

THE 'INITIALISATION' ROUTINE

The main entry point to this routine is at START/NEW (11CB). When entered from START (0000), as when power is first applied to the system, the A register holds zero and the DE register the value +FFFF. However the main entry point can also be reached following the execution of the NEW command routine.

THE 'NEW COMMAND' ROUTINE

```
11B7    NEW         DI                          Disable the maskable interrupt.
                    LD      A,+FF               The NEW flag.
                    LD      DE,(RAMTOP)         The existing value of RAMTOP
                                                is preserved.
                    EXX                         Load the alternate registers
                    LD      BC,(P-RAMT)         with the following system
                    LD      DE,(RASP/PIP)       variables.  All of which will
                    LD      HL,(UDG)            also be preserved.
                    EXX
```

The main entry point.

```
11CB    START/NEW   LD      B,A                 Save the flag for later.
                    LD      A,+07               Make the border white in
                    OUT     (+FE),A             colour.
                    LD      A,+3F               Set the I register to hold
                    LD      I,A                 the value of +3F.
                    DEFB    +00,+00,+00         Wait 24 T states.
                    DEFB    +00,+00,+00
```

Now the memory is checked.

```
11DA    RAM-CHECK   LD      H,D                 Transfer the value in DE
                    LD      L,E                 (START = +FFFF, NEW =
                                                RAMTOP).
11DC    RAM-FILL    LD      (HL),+02            Enter the value of +02 into
                    DEC     HL                  every location above +3FFF.
                    CP      H
                    JR      NZ,11DC,RAM-FILL
11E2    RAM-READ    AND     A                   Prepare for true subtraction.
                    SBC     HL,DE               The carry flag will become
                    ADD     HL,DE               reset when the top is reached.
                    INC     HL                  Update the pointer.
                    JR      NC,11EF,RAM-DONE    Jump when at top.
                    DEC     (HL)                +02 goes to +01.
                    JR      Z,11EF,RAM-DONE     But if zero then RAM is faulty.
                                                Use current HL as top.
                    DEC     (HL)                +01 goes to +00.
                    JR      Z,11E2,RAM-READ     Step to the next test unless it
                                                fails.
11EF    RAM-DONE    DEC     HL                  HL points to the last actual
                                                location in working order.
```

Next restore the 'preserved' system variables. (Meaningless when coming from START.)

```
                    EXX                         Switch registers.
                    LD      (P-RAMT),BC         Restore P-RAMT,RASP/PIP
                    LD      (RASP/PIP),DE       &UDG
                    LD      (UDG),HL
                    EXX
                    INC     B                   Test the START/NEW flag.
                    JR      Z,1219,RAM-SET      Jump forward if coming from
                                                the NEW command routine.
```

Overwrite the system variables when coming from START and initialise the user-defined graphics area.

```
                LD      (P-RAMT),HL     Top of physical RAM.
                LD      DE,+3EAF        Last byte of 'U' in character
                                        set.
                LD      BC,+00A8        There are this number of bytes
                                        in twenty one letters.
                EX      DE,HL           Switch the pointers.
                LDDR                    Now copy the character forms
                                        of the letter 'A' to 'U'.
                EX      DE,HL           Switch the pointers back.
                INC     HL              Point to the first byte.
                LD      (UDG),HL        Now set UDG.
                DEC     HL              Down one location.
                LD      BC,+0040        Set the system variables
                LD      (RASP/PIP),BC   RASP & PIP.
```

The remainder of the routine is common to both the START and the NEW operations.

```
1219    RAM-SET LD      (RAMTOP),HL     Set RAMTOP.
                LD      HL,+3C00        Initialise the system variable
                LD      (CHARS),HL      CHARS.
```

Next the machine stack is set up.

```
                LD      HL,(RAMTOP)     The top location is made to
                LD      (HL),+3E        hold +3E.
                DEC     HL              The next location is left holding
                                        zero.
                LD      SP,HL           These two locations represent
                                        the 'last entry'.
                DEC     HL              Step down two locations to
                DEC     HL              find the correct value for
                LD      (ERR-SP),HL     ERR-SP.
```

The initialisation routine continues with:

```
                IM      1               Interrupt mode 1 is used.
                LD      IY,+5C3A        IY holds +ERR-NR always.
                EI                      The maskable interrupt can now
                                        be enabled.  The real-time clock
                                        will be updated and the keyboard
                                        scanned every 1/50th of a
                                        second.
                LD      HL,+5CB6        The base address of the
                LD      (CHANS),HL      channel information area.
                LD      DE,15AF         The initial channel data
                LD      BC,+0015        is moved from the table
                EX      DE,HL           (15AF) to the channel
                LDIR                    information area.
                EX      DE,HL           The system variable DATADD
                DEC     HL              is made to point to the last
                LD      (DATADD),HL     location of the channel data.
                INC     HL              And PROG & VARS to the
                LD      (PROG),HL       the location after that.
                LD      (VARS),HL
                LD      (HL),+80        The end-marker of the
                                        variables area.
                INC     HL              Move on one location to find
                LD      (E-LINE),HL     the value for E-LINE.
                LF      (HL),+0D        Make the edit-line be a single
                INC     HL              'carriage return' character.
                LD      (HL),+80        Now enter an end-marker.
                INC     HL              Move on one location to find
                LD      (WORKSP),HL     the value for WORKSP, STKBOT
                LD      (STKBOT),HL     & STKEND.
```

```
                LD      (STKEND),HL
                LD      A,+38           Initialise the colour system
                LD      (ATTR-P),A      variables to : FLASH 0,
                LD      (ATTR-T),A      BRIGHT 0, PAPER 7, & INK 0.
                LD      (BORDCR),A
                LD      HL,+0523        Initialise the system
                LD      (REPDEL),HL     variables REPDEL & REPPER.
                DEC     (KSTATE-0)      Make KSTATE-0 hold +FF
                DEC     (KSTATE-4)      Make KSTATE-4 hold +FF
                LD      HL,+15C6        Next move the initial stream
                LD      DE,+5C10        data from its table to the
                LD      BC,+000E        streams area.
                LDIR
                SET     1,(FLAGS)       Signal 'printer in use'
                CALL    0EDF,CLEAR-PRB  and clear the printer buffer.
                LD      (DF-SZ),+02     Set the size of the lower
                CALL    0D6B,CLS        part of the display and clear
                                        the whole display.
                XOR     A               Now print the message
                LD      DE,+1538        '© 1982 Sinclair Research Ltd'
                CALL    0C0A,PO-MSG     on the bottom line.
                SET     5,(TV-FLAG)     Signal 'the lower part will
                                        required to be cleared.
                JR      12A9,MAIN-1     Jump forward into the main
                                        execution loop.
```

THE 'MAIN EXECUTION' LOOP

The main loop extends from location 12A2 to location 15AE and it controls the 'editing mode', the execution of direct commands and the production of reports.

```
12A2    MAIN-EXEC   LD      (DF-SZ),+02     The lower part of the screen
                                            is to be two lines in size.
                    CALL    1795,AUTO-LIST  Produce an automatic listing.
12A9    MAIN-1      CALL    16B0,SET-MIN    All the areas from E-LINE
                                            onwards are given their
                                            minimum configurations.

12AC    MAIN-2      LD      A,+00           Channel 'K' is opened before
                    CALL    1601,CHAN-OPEN  calling the EDITOR.
                    CALL    0F2C,EDITOR     The EDITOR is called to allow
                                            the user to build up a BASIC line.
                    CALL    1B17,LINE-SCAN  The current line is scanned for
                                            correct syntax.
                    BIT     7,(ERR-NR)      Jump forward if the syntax is
                    JR      NZ,12CF,MAIN-3  correct.
                    BIT     4,(FLAGS2)      Jump forward if other than
                    JR      Z,1303,MAIN-4   channel 'K' is being used.
                    LD      HL,(E-LINE)     Point to the start of the line
                                            with the error.
                    CALL    11A7,REMOVE-FP  Remove the floating-point
                                            forms from this line.
                    LD      (ERR-NR),+FF    Reset ERR-NR and jump back
                    JR      12AC,MAIN-2     to MAIN-2 leaving the listing
                                            unchanged.
```

The 'edit-line' has passed syntax and the three types of line that are possible have to be distinguished from each other.

```
12CF    MAIN-3      LD      HL,(E-LINE)     Point to the start of the line.
                    LD      (CH-ADD),HL     Set CH-ADD to the start also.
                    CALL    19FB,E-LINE-NO  Fetch any line number into BC.
                    LD      A,B             Is the line number a valid
                    OR      C               one?
                    JR      NZ,155D,MAIN-ADD Jump if it is so, and add the new
                                            line to the existing program.
```

```
                RST     0018            Fetch the first character of
                CP      +0D             the line and see if the line is
                                        'carriage return only'.
                JR      Z,12A2,MAIN-EXEC If it is then jump back.
```

The 'edit-line' must start with a direct BASIC command so this line becomes the first line to be interpreted.

```
                BIT     0,(FLAGS2)      Clear the whole display unless
                CALL    NZ,0DAF,CL-ALL  the flag says it is unnecessary.
                CALL    0D6E,CLS-LOWER  Clear the lower part anyway.
                LD      A,+19           Set the appropriate value
                SUB     (S-POSN-hi)     for the scroll counter.
                LD      (SCR-CT),A
                SET     7,(FLAGS)       Signal 'line execution'.
                LD      (ERR-NR),+FF    Ensure ERR-NR is correct.
                LD      (NSPPC),+01     Deal with the first statement in
                                        the line.
                CALL    1B8A,PROG-RUN   Now the line is interpreted.
                                        Note: The address 1303 goes on
                                        to the machine stack and is
                                        addressed by ERR-SP.
```

After the line has been interpreted and all the actions consequential to it have been completed a return is made to MAIN-4, so that a report can be made.

```
1303    MAIN-4  HALT                    The maskable interrupt must be
                                        enabled.
                RES     5,(FLAGS)       Signal 'ready for a new key'.
                BIT     1,(FLAGS2)      Empty the printer buffer if
                CALL    NZ,0ECD,COPY-BUFF it has been used.
                LD      A,(ERR-NR)      Fetch the error number and
                INC     A               increment it.
1313    MAIN-G  PUSH    AF              Save the new value.
                LD      HL,+0000        The system variables
                LD      (FLAGX),H       FLAGX, X-PTR-hi &
                LD      (X-PTR-hi),H    DEFADD are all set to zero.
                LD      (DEFADD),HL
                LD      HL,+0001        Ensure that stream +00
                LD      (STRMS-6),HL    points to channel 'K'
                CALL    16B0,SET-MIN    Clear all the work areas and the
                                        calculator stack.
                RES     5,(FLAGX)       Signal 'editing mode'.
                CALL    0D6E,CLS-LOWER  Clear the lower screen.
                SET     5,(TV-FLAG)     Signal 'the lower screen will
                                        require clearing'.
                POP     AF              Fetch the report value.
                LD      B,A             Make a copy in B.
                CP      +0A             Jump forward with report
                JR      C,133C,MAIN-5   numbers '0 to 9'.
                ADD     A,+07           Add the ASCII letter
                                        offset value.
133C    MAIN-5  CALL    15EF,OUT-CODE   Print the report code and
                LD      A,+20           follow it with a 'space'.
                RST     0010,PRINT-A-1
                LD      A,B             Fetch the report value and
                LD      DE,+1391        use it to identify the
                CALL    0C0A,PO-MSG     required report message.
                XOR     A               Print the message and follow
                LD      DE,+1536        it by a 'comma' and a 'space'.
                CALL    0C0A,PO-MSG
                LD      BC,(PPC)        Now fetch the current line
                CALL    1A1B,OUT-NUM1   number and print it as well.
                LD      A,+3A           Follow it by a ':'
                RST     0010,PRINT-A-1
```

```
                LD      C,(SUBPPC)      Fetch the current statement
                LD      B,+00           number into the BC register
                CALL    1A1B,OUT-NUM1   pair and print it.
                CALL    1097,CLEAR-SP   Clear the editing area.
                LD      A,(ERR-NR)      Fetch the error number again.
                INC     A               Increment it as usual.
                JR      Z,1386,MAIN-9   If the program was completed
                                        successfully there cannot be
                                        any 'CONTinuing' so jump.
                CP      +09             If the program halted with
                JR      Z,1373,MAIN-6   'STOP statement' or 'BREAK
                CP      +15             into program' CONTinuing will
                JR      NZ,1376,MAIN-7  be from the next statement;
1373    MAIN-6  INC     (SUBPPC)        otherwise SUBPPC is unchanged.
1376    MAIN-7  LD      BC,+0003        The system variables OLDPPC
                LD      DE,+5C70        & OSPCC have now to be made
                                        to hold the CONTinuing line
                                        and statement numbers.
                LD      HL,+5C44        The values used will be those in
                BIT     7,(NSPPC)       PPC & SUBPPC unless NSPPC
                JR      Z,1384,MAIN-8   indicates that the 'break'
                ADD     HL,BC           occurred before a 'jump'.
1384    MAIN-8  LDDR                    (i.e. after a GO TO statement
                                        etc.)
1386    MAIN-9  LD      (NSPPC),+FF     NSPPC is reset to indicate
                                        'no jump'.
                RES     3,(FLAGS)       'K mode' is selected.
                JP      12AC,MAIN-2     And finally the jump back is
                                        made but no program listing
                                        will appear until requested.
```

THE REPORT MESSAGES

Each message is given with the last character inverted (+80 hex.).

```
1391    DEFB +80        - initial byte is stepped over.
1392    Report 0        - 'OK'
1394    Report 1        - 'NEXT without FOR'
13A4    Report 2        - 'Variable not found'
13B6    Report 3        - 'Subscript wrong'
13C6    Report 4        - 'Out of memory'
13D2    Report 5        - 'Out of screen'
13DF    Report 6        - 'Number too big'
13ED    Report 7        - 'RETURN without GOSUB'
1401    Report 8        - 'End of file'
140C    Report 9        - 'STOP statement'
141A    Report A        - 'Invalid argument'
142A    Report B        - 'Integer out of range'
143E    Report C        - 'Nonsense in BASIC'
144F    Report D        - 'BREAK - CONT repeats'
1463    Report E        - 'Out of DATA'
146E    Report F        - 'Invalid file name'
147F    Report G        - 'No room for line'
148F    Report H        - 'STOP in INPUT'
149C    Report I        - 'FOR without NEXT'
14AC    Report J        - 'Invalid I/O device'
14BE    Report K        - 'Invalid colour'
14CC    Report L        - 'BREAK into program'
14DE    Report M        - 'RAMTOP no good'
14EC    Report N        - 'Statement lost'
14FA    Report O        - 'Invalid stream'
1508    Report P        - 'FN without DEF'
1516    Report Q        - 'Parameter error'
1525    Report R        - 'Tape loading error'
```

There are also the following two messages.

1537	', '	- a 'comma' and a 'space'
1539	'© 1982 Sinclair Research Ltd'	

Report G - No room for line

1555	REPORT-G	LD	A,+10	'G' has the code '10+07+30'
		LD	BC,+0000	Clear BC.
		JP	1313,MAIN-G	Jump back to give the report.

THE 'MAIN-ADD' SUBROUTINE

This subroutine allows for a new BASIC line to be added to the existing BASIC program in the program area. If a line has both an old and a new version then the old one is 'reclaimed'. A new line that consists of only a line number does not go into the program area.

155D	MAIN-ADD	LD	(E-PPC),BC	Make the new line number the 'current line'.
		LD	HL,(CH-ADD)	Fetch CH-ADD and save the
		EX	DE,HL	address in DE.
		LD	HL,+1555	Push the address of REPORT-G
		PUSH	HL	on to the machine stack. ERR-SP will now point to REPORT-G.
		LD	HL,(WORKSP)	Fetch WORKSP.
		SCF		Find the length of the line
		SBC,	HL,DE	from after the line number to the 'carriage return' character inclusively.
		PUSH	HL	Save the length.
		LD	H,B	Move the line number to the
		LD	L,C	HL register pair.
		CALL	196E,LINE-ADDR	Is there an existing line with this number?
		JR	NZ,157D,MAIN-ADD1	Jump if there was not.
		CALL	19B8,NEXT-ONE	Find the length of the 'old'
		CALL	19E8,RECLAIM-2	line and reclaim it.
157D	MAIN-ADD1	POP	BC	Fetch the length of the
		LD	A,C	'new' line and jump forward
		DEC	A	if it is only a 'line number
		OR	B	and a carriage return'.
		JR	15AB,MAIN-ADD2	
		PUSH	BC	Save the length.
		INC	BC	Four extra locations will be
		INC	BC	needed.
		INC	BC	i.e. two for the number &
		INC	BC	two for the length.
		DEC	HL	Make HL point to the location before the 'destination'.
		LD	DE,(PROG)	Save the current value of
		PUSH	DE	PROG to avoid corruption when adding a first line.
		CALL	1655,MAKE-ROOM	Space for the new line is created.
		POP	HL	The old value of PROG is
		LD	(PROG),HL	fetched and restored.
		POP	BC	A copy of the line length
		PUSH	BC	(without parameters) is taken.
		INC	DE	Make DE point to the end location of the new area
		LD	HL,(WORKSP)	and HL to the 'carriage
		DEC	HL	return' character of the new
		DEC	HL	line in the editing area.
		LDDR		Now copy over the line.
		LD	HL,(E-PPC)	Fetch the line's number.

```
                    EX      DE,HL           Destination into HL &
                                            number into DE.
                    POP     BC              Fetch the new line's length.
                    LD      (HL),B          The high length byte.
                    DEC     HL
                    LD      (HL),C          The low length byte.
                    DEC     HL
                    LD      (HL),E          The low line number byte.
                    DEC     HL
                    LD      (HL),D          The high line number byte.
15AB  MAIN-ADD2     POP     AF              Drop the address of REPORT-G.
                    JP      12A2,MAIN-EXEC  Jump back and this time do
                                            produce and automatic listing.
```

THE 'INITIAL CHANNEL INFORMATION'

Initially there are four channels - 'K', 'S', 'R', & 'P' - for communicating with the 'keyboard', 'screen', 'work space' and 'printer'. For each channel the output routine address comes before the input routine address and the channel's code.

```
15AF  DEFB      F4 09                   - PRINT-OUT
      DEFB      A8 10                   - KEY-INPUT
      DEFB      4B                      - 'K'
15B4  DEFB      F4 09                   - PRINT-OUT
      DEFB      C4 15                   - REPORT-J
      DEFB      53                      - 'S'
15B9  DEFB      81 0F                   - ADD-CHAR
      DEFB      C4 15                   - REPORT-J
      DEFB      52                      - 'R'
15BE  DEFB      F4 09                   - PRINT-OUT
      DEFB      C4 15                   - REPORT-J
      DEFB      50                      - 'P'
15C3  DEFB      80                      - End marker.

Report J - Invalid I/O device
15C4  REPORT-J  RST     0008,ERROR-1    Call the error handling
                DEFB    +12             routine
```

THE 'INITIAL STREAM DATA'

Initially there are seven streams - +FD to +03.

```
15C6  DEFB  01 00   - stream +FD leads to channel   'K'
15C8  DEFB  06 00   - stream +FE  "        "        'S'
15CA  DEFB  0B 00   - stream +FF  "        "        'R'
15CC  DEFB  01 00   - stream +00  "        "        'K'
15CE  DEFB  01 00   - stream +01  "        "        'K'
15D0  DEFB  06 00   - stream +02  "        "        'S'
15D2  DEFB  10 00   - stream +03  "        "        'P'
```

THE 'WAIT-KEY' SUBROUTINE

This subroutine is the controlling subroutine for calling the current input subroutine.

```
15D4  WAIT-KEY      BIT     5,(TV-FLAG)         Jump forward if the flag
                    JR      NZ,15DE,WAIT-KEY1   indicates the lower screen
                                                does not require clearing.
                    SET     3,(TV-FLAG)         Otherwise signal 'consider
                                                the mode as having changed'.
15DE  WAIT-KEY1     CALL    15E6,INPUT-AD       Call the input subroutine
                                                indirectly via INPUT-AD.
                    RET     C                   Return with acceptable codes.
                    JR      Z,15DE,WAIT-KEY1    Both the carry flag and the
                                                zero flag are reset if 'no key is
                                                being pressed'; otherwise
                                                signal an error.
```

Report 8 - End of file

```
15E4    REPORT-8    RST     0008,ERROR-1        Call the error handling
                    DEFB    +07                 routine.
```

THE 'INPUT-AD' SUBROUTINE

The registers are saved and HL made to point to the input address.

```
15E6    INPUT-AD    EXX                         Save the registers.
                    PUSH    HL
                    LD      HL,(CURCHL)         Fetch the base address for the
                                                current channel information.
                    INC     HL                  Step past the output address.
                    INC     HL
                    JR      15F7,CALL-SUB       Jump forward.
```

THE 'MAIN PRINTING' SUBROUTINE

The subroutine is called with either an absolute value or a proper character code in the A register.

```
15EF    OUT-CODE    LD      E,+30               Increase the value in the
                    ADD     A,E                 A register by +30.
15F2    PRINT-A-2   EXX                         Again save the registers.
                    PUSH    HL
                    LD      HL,(CURCHL)         Fetch the base address for the
                                                current channel.  This will point
                                                to an output address.
```

Now call the actual subroutine. HL points to the output or the input address as directed.

```
15F7    CALL-SUB    LD      E,(HL)              Fetch the low byte.
                    INC     HL
                    LD      D,(HL)              Fetch the high byte.
                    EX      DE,HL               Move the address to the HL
                                                register pair.
                    CALL    162C,CALL-JUMP      Call the actual subroutine.
                    POP     HL                  Restore the registers.
                    EXX
                    RET                         Return will be from here
                                                unless an error occurred.
```

THE 'CHAN-OPEN' SUBROUTINE

This subroutine is called with the A register holding a valid stream number - normally +FD to +03. Then depending on the stream data a particular channel will be made the current channel.

```
1601    CHAN-OPEN   ADD     A,A                 The value in the A register is
                    ADD     A,+16               doubled and then increased by
                    LD      L,A                 +16.  The result is moved to L.
                    LD      H,+5C               The address 5C16 is the base
                                                address for stream +00.
                    LD      E,(HL)              Fetch the first byte of the
                    INC     HL                  required stream's data; then
                    LD      D,(HL)              the second byte.
                    LD      A,D                 Give an error if both bytes
                    OR      E                   are zero; otherwise jump
                    JR      NZ,1610,CHAN-OP-1   forward.
```

Report O - Invalid stream

```
160E    REPORT-O    RST     0008,ERROR-1        Call the error handling
                    DEFB    +17                 routine.
```

Using the stream data now find the base address of the channel information associated with that stream.

```
1610    CHAN-OP-1   DEC     DE                  Reduce the stream data.
                    LD      HL,(CHANS)          The base address of the whole
                                                channel information area.
```

```
                ADD     HL,DE           Form the required address in
                                        this area.
```

THE 'CHAN-FLAG' SUBROUTINE

The appropriate flags for the different channels are set by this subroutine.

```
1615  CHAN-FLAG LD      (CURCHL),HL     The HL register pair holds the
                                        base address for a particular
                                        channel.
                RES     4,(FLAGS2)      Signal 'using other than channel
                                        'K''.
                INC     HL              Step past the output
                INC     HL              and the input addresses and
                INC     HL              make HL point to the
                INC     HL              channel code.
                LD      C,(HL)          Fetch the code.
                LD      HL,+162D        The base address of the 'channel
                                        code look-up table'.
                CALL    16DC,INDEXER    Index into this table and locate
                                        the required offset; but return if
                RET     NC              there is not a matching channel
                                        code.
                LD      D,+00           Pass the offset to the
                LD      E,(HL)          DE register pair.
                ADD     HL,DE           Jump forward to the appropriate
162C  CALL-JUMP JP      (HL)            flag setting routine.
```

THE 'CHANNEL CODE LOOK-UP' TABLE

```
162D  DEFB  4B 06     - channel 'K',    offset +06,   address 1634
162F  DEFB  53 12     - channel 'S',    offset +12,   address 1642
1631  DEFB  50 1B     - channel 'P',    offset +1B,   address 164D
1633  DEFB  00        - end marker.
```

THE 'CHANNEL 'K' FLAG' SUBROUTINE

```
1634  CHAN-K    SET     0,(TV-FLAG)     Signal 'using lower screen'.
                RES     5,(FLAGS)       Signal 'ready for a key'.
                SET     4,(FLAGS2)      Signal 'using channel 'K''.
                JR      1646,CHAN-S-1   Jump forward.
```

THE 'CHANNEL 'S' FLAG' SUBROUTINE

```
1642  CHAN-S    RES     0,(TV-FLAG)     Signal 'using main screen'.
1646  CHAN-S-1  RES     1,(FLAGS)       Signal 'printer not being used'.
                JP      0D4D,TEMPS      Exit via TEMPS so as to set the
                                        colour system variables.
```

THE 'CHANNEL 'P' FLAG' SUBROUTINE

```
164D  CHAN-P    SET     1,(FLAGS)       Signal 'printer in use'.
                RET
```

THE 'MAKE-ROOM' SUBROUTINE

This is a very important subroutine. It is called on many occasions to 'open up' an area. In all cases the HL register pair points to the location after the place where 'room' is required and the BC register pair holds the length of the 'room' needed. When a single space only is required then the subroutine is entered at ONE-SPACE.

```
1652  ONE-SPACE LD      BC,+0001        Just the single extra location
                                        is required.
1655  MAKE-ROOM PUSH    HL              Save the pointer.
                CALL    1F05,TEST-ROOM  Make sure that there is sufficient
                                        memory available for the task
                                        being undertaken.
                POP     HL              Restore the pointer.
```

```
                CALL    1664,POINTERS   Alter all the pointers before
                                        making the 'room'.
                LD      HL,(STKEND)     Make HL hold the new STKEND.
                EX      DE,HL           Switch 'old' and 'new'.
                LDDR                    Now make the 'room'
                RET                     and return.
```

Note: This subroutine returns with the HL register pair pointing to the location before the new 'room' and the DE register pair pointing to the last of the new locations. The new 'room' therefore has the description: '(HL)+1' to '(DE)' inclusive.
However as the 'new locations' still retain their 'old values' it is also possible to consider the new 'room' as having been made after the original location '(HL)' and it thereby has the description '(HL)+2' to (DE)+1'.
In fact the programmer appears to have a preference for the 'second description' and this can be confusing.

THE 'POINTERS' SUBROUTINE

Whenever an area has to be 'made' or 'reclaimed' the system variables that address locations beyond the 'position' of the change have to be amended as required. On entry the BC register pair holds the number of bytes involved and the HL register pair addresses the location before the 'position'.

```
1664    POINTERS    PUSH    AF              These registers are saved.
                    PUSH    HL              Copy the address of the
                                            'position'.
                    LD      HL,+5C4B        This is VARS, the first of the
                    LD      A,+0E           fourteen system pointers.
```

A loop is now entered to consider each pointer in turn. Only those pointers that point beyond the 'position' are changed.

```
166B    PTR-NEXT    LD      E,(HL)          Fetch the two bytes of the
                    INC     HL              current pointer.
                    LD      D,(HL)
                    EX      (SP),HL         Exchange the system variable
                                            with the address of the 'position'.
                    AND     A               The carry flag will become
                    SBC     HL,DE           set if the system variable's
                    ADD     HL,DE           address is to be updated.
                    EX      (SP),HL         Restore the 'position'.
                    JR      NC,167F,PTR-DONE Jump forward if the pointer is
                                            to be left; otherwise change it.
                    PUSH    DE              Save the old value.
                    EX      DE,HL           Now add the value in BC
                    ADD     HL,BC           to the old value.
                    EX      DE,HL
                    LD      (HL),D          Enter the new value into the
                    DEC     HL              system variable - high byte
                    LD      (HL),E          before low byte.
                    INC     HL              Point again to the high byte.
                    POP     DE              Fetch the old value.
167F    PTR-DONE    INC     HL              Point to the next system
                    DEC     A               variable and jump back until all
                    JR      NZ,166B,PTR-NEXT fourteen have been considered.
```

Now find the size of the block to be moved.

```
                    EX      DE,HL           Put the old value of STKEND in
                    POP     DE              HL and restore the other
                    POP     AF              registers.
                    AND     A               Now find the difference
                    SBC     HL,DE           between the old value of
                    LD      B,H             STKEND and the 'position'.
                    LD      C,L             Transfer the result to BC
                    INC     BC              and add '1' for the inclusive
                                            byte.
```

```
                ADD     HL,DE           Reform the old value of
                EX      DE,HL           STKEND and pass it to DE
                RET                     before returning.
```

THE 'COLLECT A LINE NUMBER' SUBROUTINE

On entry the HL register pair points to the location under consideration. If the location holds a value that constitutes a suitable high byte for a line number then the line number is returned in DE. However if this is not so then the location addressed by DE is tried instead; and should this also be unsuccessful line number zero is returned.

```
168F    LINE-ZERO   DEFB    +00             Line number zero.
                    DEFB    +00
1691    LINE-NO-A   EX      DE,HL           Consider the other pointer.
                    LD      DE,+168F        Use line number zero.
```

The usual entry point is at LINE-NO.

```
1695    LINE-NO     LD      A,(HL)          Fetch the high byte and
                    AND     +C0             test it.
                    JR      NZ,1691,LINE-NO-A  Jump back if not suitable.
                    LD      D,(HL)          Fetch the high byte.
                    INC     HL
                    LD      E,(HL)          Fetch the low byte and
                    RET                     return.
```

THE 'RESERVE' SUBROUTINE

This subroutine is normally called by using RST 0030,BC-SPACES.
On entry here the last value on the machine stack is WORKSP and the value above it is the number of spaces that is to be 'reserved'.
This subroutine always makes 'room' between the existing work space and the calculator stack.

```
169E    RESERVE     LD      HL,(STKBOT)     Fetch the current value of
                    DEC     HL              STKBOT and decrement it to
                                            get the last location of the
                                            work space.
                    CALL    1655,MAKE-ROOM  Now make 'BC spaces'.
                    INC     HL              Point to the first new space
                    INC     HL              and then the second.
                    POP     BC              Fetch the old value of
                    LD      (WORKSP),BC     WORKSP and restore it.
                    POP     BC              Restore BC - number of spaces.
                    EX      DE,HL           Switch the pointers,
                    INC     HL              Make HL point to the first of
                                            the displaced bytes.
                    RET                     Now return.
```

Note: It can also be considered that the subroutine returns with the DE register pair pointing to a 'first extra byte' and the HL register pair pointing to a 'last extra byte', these extra bytes having been added after the original '(HL)+1' location.

THE 'SET-MIN' SUBROUTINE

This subroutine resets the editing area and the areas after it to their minimum sizes. In effect it 'clears' the areas.

```
16B0    SET-MIN     LD      HL,(E-LINE)     Fetch E-LINE.
                    LD      (HL),+0D        Make the editing area hold
                    LD      (K-CUR),HL      only the 'carriage return'
                    INC     HL              character and the end marker.
                    LD      (HL),+80
                    INC     HL              Move on to clear the work
                    LD      (WORKSP),HL     space.
```

Entering here will 'clear' the work space and the calculator stack.

```
16BF    SET-WORK    LD      HL,(WORKSP)     Fetch the WORKSP.
                    LD      (STKBOT),HL     This clears the work space.
```

Entering here will 'clear' only the calculator stack.

```
16C5    SET-STK     LD      HL,(STKBOT)     Fetch STKBOT.
                    LD      (STKEND),HL     This clears the stack.
```

In all cases make MEM address the calculator's memory area.

```
                    PUSH    HL              Save STKEND.
                    LD      HL,+5C92        The base of the memory area.
                    LD      (MEM),HL        Set MEM to this address.
                    POP     HL              Restore STKEND to the HL
                    RET                     register pair before returning.
```

THE 'RECLAIM THE EDIT-LINE' SUBROUTINE'

```
16D4    REC-EDIT    LD      DE,(E-LINE)     Fetch E-LINE.
                    JP      19E5,RECLAIM-1  Reclaim the memory.
```

THE 'INDEXER' SUBROUTINE

This subroutine is used on several occasions to look through tables. The entry point is at INDEXER.

```
16DB    INDEXER-1   INC     HL              Move on to consider the next
                                            pair of entries.
16DC    INDEXER     LD      A,(HL)          Fetch the first of a pair of
                    AND     A               entries but return if it is
                    RET     Z               zero - the end marker.
                    CP      C               Compare it to the supplied
                                            code.
                    INC     HL              Point to the second entry.
                    JR      NZ,16DB,INDEXER-1 Jump back if the correct entry
                                            has not been found.
                    SCF                     The carry flag is set upon a
                    RET                     successful search.
```

THE 'CLOSE #' COMMAND ROUTINE

This command allows the user to CLOSE streams. However for streams +00 to +03 the 'initial' stream data is restored and these streams cannot therefore be CLOSEd.

```
16E5    CLOSE       CALL    171E,STR-DATA   The existing data for the stream
                                            is fetched.
                    CALL    1701,CLOSE-2    Check the code in that
                                            stream's channel.
                    LD      BC,+0000        Prepare to make the stream's
                                            data zero.
                    LD      DE,+A3E2        Prepare to identify the use of
                    EX      DE,HL           streams +00 to +03.
                    ADD     HL,DE           The carry flag will be set with
                                            streams +04 to +0F.
                    JR      C,16FC,CLOSE-1  Jump forward with these
                    LD      BC,+15D4        streams; otherwise find the
                    ADD     HL,BC           correct entry in the 'initial
                                            stream data' table.
                    LD      C,(HL)          Fetch the initial data
                    INC     HL              for streams +00 to +03.
                    LD      B,(HL)
16FC    CLOSE-1     EX      DE,HL           Now enter the data; either
                    LD      (HL),C          zero & zero, or the initial
                    INC     HL              values.
                    LD      (HL),B
                    RET
```

THE 'CLOSE-2' SUBROUTINE

The code of the channel associated with the stream being closed has to be 'K', 'S', or 'P'.

```
1701    CLOSE-2     PUSH    HL              Save the address of the
                                            stream's data.
```

```
                LD      HL,(CHANS)      Fetch the base address of the
                ADD     HL,BC           channel information area and
                                        find the channel data for the
                                        stream being CLOSEd.
                INC     HL              Step past the subroutine
                INC     HL              addresses and pick up
                INC     HL              the code for that channel.
                LD      C,(HL)
                EX      DE,HL           Save the pointer.
                LD      HL,+1716        The base address of the 'CLOSE
                                        stream look-up' table.
                CALL    16DC,INDEXER    Index into this table and locate
                                        the required offset.
                LD      C,(HL)          Pass the offset to the BC
                LD      B,+00           register pair.
                ADD     HL,BC           Jump forward to the
                JP      (HL)            appropriate routine.
```

THE 'CLOSE STREAM LOOK-UP' TABLE

```
1716            DEFB    4B 05       - channel 'K', offset +05, address 171C
1718            DEFB    53 03       - channel 'S', offset +03, address 171C
171A            DEFB    50 01       - channel 'P', offset +01, address 171C
```

Note: There is no end marker at the end of this table.

THE 'CLOSE STREAM' SUBROUTINE.

```
171C  CLOSE-STR POP     HL          Fetch the channel information
                RET                 pointer and return.
```

THE 'STREAM DATA' SUBROUTINE

This subroutine returns in the BC register pair the stream data for a given stream.

```
171E  STR-DATA  CALL    1E94,STK-TO-A   The given stream number is
                                        taken off the calculator stack.
                CP      +10             Give an error if the stream
                JR      C,1727,STR-DATA1 number is greater than +0F.
```

Report O - Invalid stream

```
1725  REPORT-O  RST     0008,ERROR-1    Call the error handling
                DEFB    +17             routine.
```

Continue with valid stream numbers.

```
1727  STR-DATA1 ADD     A,+03           Range now +03 to +12;
                RLCA                    and now +06 to +24.
                LD      HL,+5C10        The base address of the
                                        stream data area.
                LD      C,A             Move the stream code to the
                LD      B,+00           BC register pair.
                ADD     HL,BC           Index into the data area
                LD      C,(HL)          and fetch the two data bytes
                INC     HL              into the BC register pair.
                LD      B,(HL)
                DEC     HL              Make the pointer address the
                RET                     first of the data bytes before
                                        returning.
```

THE 'OPEN #' COMMAND ROUTINE

This command allows the user to OPEN streams. A channel code must be supplied and it must be 'K', 'k', 'S', 's', 'P', or 'p'. Note that no attempt is made to give streams +00 to +03 their initial data.

```
1736  OPEN      RST     0028,FP-CALC    Use the CALCULATOR.
                DEFB    +01,exchange    Exchange the stream number
```

```
                DEFB    +38,end-calc        and the channel code.
                CALL    171E,STR-DATA       Fetch the data for the stream.
                LD      A,B                 Jump forward if both bytes of
                OR      C                   the data are zero, i.e. the
                JR      Z,1756,OPEN-1       stream was in a closed state.
                EX      DE,HL               Save DE.
                LD      HL,(CHANS)          Fetch CHANS - the base
                ADD     HL,BC               address of the channel
                INC     HL                  information and find the
                INC     HL                  code of the channel
                INC     HL                  associated with the stream
                LD      A,(HL)              being OPENed.
                EX      DE,HL               Return DE.
                CP      +4B                 The code fetched from the
                JR      Z,1756,OPEN-1       channel information area
                CP      +53                 must be 'K', 'S' or 'P';
                JR      Z,1756,OPEN-1       give an error if it is not.
                CP      +50
                JR      NZ,1725,REPORT-O
1756    OPEN-1  CALL    175D,OPEN-2         Collect the appropriate data
                                            in DE.
                LD      (HL),E              Enter the data into the
                INC     HL                  two bytes in the stream
                LD      (HL),D              information area.
                RET                         Finally return.
```

THE 'OPEN-2' SUBROUTINE

The appropriate stream data bytes for the channel that is associated with the stream being OPENed are found.

```
175D    OPEN-2  PUSH    HL                  Save HL
                CALL    2BF1,STK-FETCH      Fetch the parameters of the
                                            channel code.
                LD      A,B                 Give an error if the
                OR      C                   expression supplied is a null
                JR      NZ,1767,OPEN-3      expression; i.e. OPEN #5,"".
```

Report F - Invalid file name

```
1765    REPORT-F RST    0008,ERROR-1        Call the error handling
                DEFB    +0E                 routine.
```

Continue if no error occurred.

```
1767    OPEN-3  PUSH    BC                  The length of the expression
                                            is saved.
                LD      A,(DE)              Fetch the first character.
                AND     +DF                 Convert lower case codes to
                                            upper case ones.
                LD      C,A                 Move code to the C register.
                LD      HL,+177A            The base address of the
                                            'OPEN stream look-up' table.
                CALL    16DC,INDEXER        Index into this table and locate
                                            the required offset.
                JR      NC,1765,REPORT-F    Jump back if not found.
                LD      C,(HL)              Pass the offset to the BC
                LD      B,+00               register pair.
                ADD     HL,BC               Make HL point to the start of
                                            the appropriate subroutine.
                POP     BC                  Fetch the length of the
                JP      (HL)                expression before jumping to
                                            the subroutine.
```

THE 'OPEN STREAM LOOK-UP' TABLE

```
177A            DEFB    4B 06               - channel 'K', offset +06, address 1781
```

```
177C            DEFB    53 08           - channel 'S', offset +08, address 1785
177E            DEFB    50 0A           - channel 'P', offset +0A, address 1789
1780            DEFB    00              - end marker;
```

THE 'OPEN-K' SUBROUTINE

```
1781  OPEN-K    LD      E,+01           The data bytes will be +01
                JR      178B,OPEN-END   & +00.
```

THE 'OPEN-S' SUBROUTINE

```
1785  OPEN-S    LD      E,+06           The data bytes will be +06
                JR      178B,OPEN-END   & +00.
```

THE 'OPEN-P' SUBROUTINE

```
1789  OPEN-P    LD      E,+10           The data bytes will be +10
                                        & +00.
178B  OPEN-END  DEC     BC              Decrease the length of the
                LD      A,B             expression and give an error
                OR      C               if it was not a single
                JR      NZ,1765,REPORT-F character; otherwise clear the
                LD      D,A             D register, fetch HL and
                POP     HL              return.
                RET
```

THE 'CAT, ERASE, FORMAT & MOVE' COMMAND ROUTINES

In the standard SPECTRUM system the use of these commands leads to the production of report O - Invalid stream.

```
1793  CAT-ETC.  JR      1725,REPORT-O   Give this report.
```

THE 'LIST & LLIST' COMMAND ROUTINES

The routines in this part of the 16K program are used to produce listings of the current BASIC program. Each line has to have its line number evaluated, its tokens expanded and the appropriate cursors positioned.
The entry point AUTO-LIST is used by both the MAIN EXECUTION routine and the EDITOR to produce a single page of the listing.

```
1795  AUTO-LIST LD      (LIST-SP),SP    The stack pointer is saved
                                        allowing the machine stack to
                                        be reset when the listing is
                                        finished.  (see PO-SCR,0C55)
                LD      (TV-FLAG),+10   Signal 'automatic listing in the
                                        main screen'.
                CALL    0DAF,CL-ALL     Clear this part of the screen.
                SET     0,(TV-FLAG)     Switch to the editing area.
                LD      B,(DF-SZ)       Now clear the lower part
                CALL    0E44,CL-LINE    of the screen as well.
                RES     0,(TV-FLAG)     Then switch back.
                SET     0,(FLAGS2)      Signal 'screen is clear'.
                LD      HL,(E-PPC)      Now fetch the 'current' line
                LD      DE,(S-TOP)      number and the 'automatic'
                                        line number.
                AND     A               If the 'current' number is
                SBC     HL,DE           less than the 'automatic'
                ADD     HL,DE           number then jump forward to
                JR      C,17E1,AUTO-L-2 update the 'automatic' number.
```

The 'automatic' number has now to be altered to give a listing with the 'current' line appearing near the bottom of the screen.

```
                PUSH    DE              Save the 'automatic' number.
                CALL    196E,LINE-ADDR  Find the address of the
                LD      DE,+02C0        start of the 'current' line
                EX      DE,HL           and produce an address roughly
```

```
                SBC     HL,DE           a 'screen before it' (negated).
                EX      (SP),HL         Save the 'result' on the machine
                CALL    196E,LINE-ADDR  stack whilst the 'automatic' line
                                        address is also found (in HL).
                POP     BC              The 'result' goes to the BC
                                        register pair.
```

A loop is now entered. The 'automatic' line number is increased on each pass until it is likely that the 'current' line will show on a listing.

```
17CE  AUTO-L-1  PUSH    BC              Save the 'result'.
                CALL    19B8,NEXT-ONE   Find the address of the start
                                        of the line after the present
                                        'automatic' line (in DE).
                POP     BC              Restore the 'result'.
                ADD     HL,BC           Perform the computation and
                JR      C,17E4,AUTO-L-3 jump forward if finished.
                EX      DE,HL           Move the next line's address
                LD      D,(HL)          to the HL register pair and
                INC     HL              collect its line number.
                LD      E,(HL)
                DEC     HL
                LD      (S-TOP),DE      Now S-TOP can be updated and
                JR      17CE,AUTO-L-1   the test repeated with the new
                                        line.
```

Now the 'automatic' listing can be made.

```
17E1  AUTO-L-2  LD      (S-TOP),HL      When E-PPC is less than S-TOP.
17E4  AUTO-L-3  LD      HL,(S-TOP)      Fetch the top line's number
                CALL    196E,LINE-ADDR  and hence its address.
                JR      Z,17ED,AUTO-L-4 If the line cannot be found
                EX      DE,HL           use DE instead.
17ED  AUTO-L-4  CALL    1833,LIST-ALL   The listing is produced.
                RES     4,(TV-FLAG)     The return will be to here
                RET                     unless scrolling was needed to
                                        show the current line.
```

THE 'LLIST' ENTRY POINT

The printer channel will need to be opened.

```
17F5  LLIST     LD      A,+03           Use stream +03.
                JR      17FB,LIST-1     Jump forward.
```

THE 'LIST' ENTRY POINT

The 'main screen' channel will need to be opened.

```
17F9  LIST      LD      A,+02           Use stream +02.
17FB  LIST-1    LD      (TV-FLAG),+00   Signal 'an ordinary listing in
                                        the main part of the screen'.
                CALL    2530,SYNTAX-Z   Open the channel unless
                CALL    NZ,1601,CHAN-OPEN checking syntax.
                RST     0018,GET-CHAR   With the present character in
                CALL    2070,STR-ALTER  the A register see if the stream
                                        is to be changed.
                JR      C,181F,LIST-4   Jump forward if unchanged.
                RST     0018,GET-CHAR   Is the present character
                CP      +3B             a ';'?
                JR      Z,1814,LIST-2   Jump if it is.
                CP      +2C             Is it a ','?
                JR      NZ,181A,LIST-3  Jump if it is not.
1814  LIST-2    RST     0020,NEXT-CHAR  A numeric expression must
                CALL    1C82,EXPT-1NUM  follow, e.g. LIST #5,20
                JR      1822,LIST-5     Jump forward with it.
181A  LIST-3    CALL    1CE6,USE-ZERO   Otherwise use zero and
                JR      1822,LIST-5     also jump forward.
```

Come here if the stream was unaltered.

```
181F  LIST-4      CALL  1CDE,FETCH-NUM     Fetch any line or use zero if
                                           none supplied.
1822  LIST-5      CALL  1BEE,CHECK-END     If checking the syntax of the
                                           edit-line move on to the next
                                           statement.
                  CALL  1E99,FIND-INT      Line number to BC.
                  LD    A,B                High byte to A.
                  AND   +3F                Limit the high byte to the
                  LD    H,A                correct range and pass the
                  LD    L,C                whole line number to HL.
                  LD    (E-PPC),HL         Set E-PPC and find the address
                  CALL  196E,LINE-ADDR     of the start of this line or the
                                           first line after it if the actual
                                           line does not exist.
1833  LIST-ALL    LD    E,+01              Flag 'before the current line'.
```

Now the controlling loop for printing a series of lines is entered.

```
1835  LIST-ALL-1  CALL  1855,OUT-LINE      Print the whole of a BASIC line.
                  RST   0010,PRINT-A-1     This will be a 'carriage return'.
                  BIT   4,(TV-FLAG)        Jump back unless dealing
                  JR    Z,1835,LIST-ALL-1  with an automatic listing.
                  LD    A,(DF-SZ)          Also jump back if there is
                  SUB   (S-POSN-hi)        still part of the main screen
                  JR    NZ,1835,LIST-ALL-1 that can be used.
                  XOR   E                  A return can be made at this
                  RET   Z                  point if the screen is full and the
                                           current line has been printed
                                           (E = +00)
                  PUSH  HL                 However if the current line is
                  PUSH  DE                 missing from the listing
                  LD    HL,+5C6C           then S-TOP has to be updated
                  CALL  190F,LN-FETCH      and a further line printed
                  POP   DE                 (using scrolling).
                  POP   HL
                  JR    1835,LIST-ALL-1
```

THE 'PRINT A WHOLE BASIC LINE' SUBROUTINE

The HL register pair points to the start of the line - the location holding the high byte of the line number.
Before the line number is printed it is tested to determine whether it comes before the 'current' line, is the 'current' line or comes after.

```
1855  OUT-LINE    LD    BC,(E-PPC)         Fetch the 'current' line
                  CALL  1980,CP-LINES      number and compare it.
                  LD    D,+3E              Pre-load the D register with the
                                           current line cursor.
                  JR    Z,1865,OUT-LINE1   Jump forward if printing the
                                           'current' line.
                  LD    DE,+0000           Load the D register with zero
                                           (it is not the cursor) and
                  RL    E                  set E to hold +01 if the line is
                                           before the 'current' line and +00
                                           if after.  (The carry flag comes
                                           from CP-LINES.)
1865  OUT-LINE1   LD    (BREG),E           Save the line marker.
                  LD    A,(HL)             Fetch the high byte of the
                  CP    +40                line number and make a full
                  POP   BC                 return if the listing has been
                  RET   NC                 finished.
                  PUSH  BC
                  CALL  1A28,OUT-NUM-2     The line number can now be
                                           printed - with leading spaces.
```

```
                INC     HL              Move the pointer on to address
                INC     HL              the first command code in
                INC     HL              the line.
                RES     0,(FLAGS)       Signal 'leading space allowed'
                LD      A,D             Fetch the cursor code and
                AND     A               jump forward unless the
                JR      Z,1881,OUT-LINE3 cursor is to be printed.
                RST     0010,PRINT-A-1  So print the cursor now.
187D  OUT-LINE2 SET     0,(FLAGS)       Signal 'no leading space now'.
1881  OUT-LINE3 PUSH    DE              Save the registers.
                EX      DE,HL           Move the pointer to DE.
                RES     2,(FLAGS2)      Signal 'not in quotes'.
                LD      HL,+5C3B        This is FLAGS.
                RES     2,(HL)          Signal 'print in K-mode'.
                BIT     5,(FLAGX)       Jump forward unless in
                JR      1894,OUT-LINE4  INPUT mode.
                SET     2,(HL)          Signal 'print in L-mode'.
```

Now enter a loop to print all the codes in the rest of the BASIC line - jumping over floating-point forms as necessary.

```
1894  OUT-LINE4 LD      HL,(X-PTR)      Fetch the syntax error
                AND     A               pointer and jump forward
                SBC     HL,DE           unless it is time to print
                JR      NZ,18A1,OUT-LINE5 the error marker.
                LD      A,+3F           Print the error marker now.
                CALL    18C1,OUT-FLASH  It is a flashing '?'.
18A1  OUT-LINE5 CALL    18E1,OUT-CURS   Consider whether to print the
                                        cursor.
                EX      DE,HL           Move the pointer to HL now.
                LD      A,(HL)          Fetch each character in turn.
                CALL    18B6,NUMBER     If the character is a 'number
                                        marker' then the hidden floating-
                                        point form is not to be printed.
                INC     HL              Update the pointer for the next
                                        pass.
                CP      +0D             Is the character a 'carriage
                                        return'.
                JR      Z,18B4,OUT-LINE6 Jump if it is.
                EX      DE,HL           Switch the pointer to DE.
                CALL    1937,OUT-CHAR   Print the character.
                JR      1894,OUT-LINE4  Go around the loop for at least
                                        one further pass.
```

The line has now been printed.

```
18B4  OUT-LINE6 POP     DE              Restore the DE register pair
                RET                     and return.
```

THE 'NUMBER' SUBROUTINE
If the A register holds the 'number marker' then the HL register pair is advanced past the floating-point form.

```
18B6  NUMBER    CP      +0E             Is the character a 'number
                RET     NZ              marker'.  Return if not.
                INC     HL              Advance the pointer six
                INC     HL              times so as to step past the
                INC     HL              'number marker' and the five
                INC     HL              locations holding the
                INC     HL              floating-point form.
                INC     HL
                LD      A,(HL)          Fetch the current code before
                RET                     returning.
```

THE 'PRINT A FLASHING CHARACTER' SUBROUTINE

The 'error cursor' and the 'mode cursors' are printed using this subroutine.

```
18C1    OUT-FLASH   EXX                         Save the current register.
                    LD      HL,(ATTR-T)         Save the ATTR-T & MASK-T on
                    PUSH    HL                  the machine stack.
                    RES     7,H                 Ensure that FLASH is
                    SET     7,L                 active.
                    LD      (ATTR-T),HL         Use these modified values
                                                for ATTR-T & MASK-T.
                    LD      HL,+5C91            This is P-FLAG.
                    LD      D,(HL)              Save P-FLAG also on the
                    PUSH    DE                  machine stack.
                    LD      (HL),+00            Ensure INVERSE 0, OVER 0,
                                                and not PAPER 9 nor INK 9.
                    CALL    09F4,PRINT-OUT      The character is printed.
                    POP     HL                  The former value of P-FLAG
                    LD      (P-FLAG),H          is restored.
                    POP     HL                  The former values of ATTR-T
                    LD      (ATTR-T),HL         & MASK-T are also restored
                    EXX                         before returning.
                    RET
```

THE 'PRINT THE CURSOR' SUBROUTINE

A return is made if it is not the correct place to print the cursor but if it is then either 'C', 'E', 'G', 'K' or 'L' will be printed.

```
18E1    OUT-CURS    LD      HL,(K-CUR)          Fetch the address of the
                    AND     A                   cursor but return if the
                    SBC     HL,DE               correct place is not being
                    RET     NZ                  considered.
                    LD      A,(MODE)            The current value of MODE is
                    RLC     A                   fetched and doubled.
                    JR      Z,18F3,OUT-C-1      Jump forward unless dealing with
                                                Extended mode or Graphics.
                    ADD     A,+43               Add the appropriate offset to
                                                give 'E' or 'G'.
                    JR      1909,OUT-C-2        Jump forward to print it.
18F3    OUT-C-1     LD      HL,+5C3B            This is FLAGS.
                    RES     3,(HL)              Signal 'K-mode'.
                    LD      A,+4B               The character 'K'.
                    BIT     2,(HL)              Jump forward to print 'K'.
                    JR      Z,1909,OUT-C-2      If 'the printing is to be in
                                                K-mode'.
                    SET     3,(HL)              The 'printing is to be in L-mode'
                                                so signal 'L-MODE'.
                    INC     A                   Form the character 'L'.
                    BIT     3,(FLAGS2)          Jump forward if not in
                    JR      Z,1909,OUT-C-2      'C-mode'.
                    LD      A,+43               The character 'C'.
1909    OUT-C-2     PUSH    DE                  Save the DE register pair
                    CALL    18C1,OUT-FLASH      whilst the cursor is printed
                    POP     DE                  - FLASHing.
                    RET                         Return once it has been done.
```

Note: It is the action of considering which cursor-letter is to be printed that determines the mode - 'K' vs. 'L/C'.

THE 'LN-FETCH' SUBROUTINE

This subroutine is entered with the HL register pair addressing a system variable - S-TOP or E-PPC.
The subroutine returns with the system variable holding the line number of the following line.

```
190F    LN-FETCH    LD      E,(HL)              The line number held by the
                    INC     HL                  system variable is collected.
```

```
                LD      D,(HL)
                PUSH    HL          The pointer is saved.
                EX      DE,HL       The line number is moved to the
                INC     HL          HL register pair and incremented.
                CALL    196E,LINE-ADDR  The address of the start of this
                                        line is found, or the next line
                                        if the actual line number is not
                                        being used.
                CALL    1695,LINE-NO    The number of that line is
                                        fetched.
                POP     HL          The pointer to the system
                                        variable is restored.
```

The entry point LN-STORE is used by the EDITOR.

```
191C  LN-STORE  BIT     5,(FLAGX)   Return if in 'INPUT mode';
                RET     NZ          otherwise proceed to
                LD      (HL),D      enter the line number into
                DEC     HL          the two locations of the
                LD      (HL),E      system variable.
                RET                 Return when it has been done.
```

THE 'PRINTING CHARACTERS IN A BASIC LINE' SUBROUTINE

All of the character/token codes in a BASIC line are printed by repeatedly calling this subroutine.
The entry point OUT-SP-NO is used when printing line numbers which may require leading spaces.

```
1925  OUT-SP-2  LD      A,E         The A register will hold +20 for
                                    a space or +FF for no-space.
                AND     A           Test the value and return if
                RET     M           there is not to be a space.
                JR      1937,OUT-CHAR   Jump forward to print a space
192A  OUT-SP-NO XOR     A           Clear the A register.
```

The HL register pair holds the line number and the BC register the value for 'repeated subtraction'. (BC holds '-1000, -100 or -10'.)

```
192B  OUT-SP-1  ADD     HL,BC       The 'trial subtraction'.
                INC     A           Count each 'trial'.
                JR      C,192B,OUT-SP-1 Jump back until exhausted.
                SBC     HL,BC       Restore last 'subtraction'
                DEC     A           and discount it.
                JR      Z,1925,OUT-SP-2 If no 'subtractions' were possible
                                        jump back to see if a space is to
                                        be printed.
                JP      15EF,OUT-CODE   Otherwise print the digit.
```

The entry point OUT-CHAR is used for all characters, tokens and control characters.

```
1937  OUT-CHAR  CALL    2D1B,NUMERIC    Return carry reset if handling a
                                        digit code.
                JR      NC,196C,OUT-CH-3    Jump forward to print the digit.
                CP      +21         Also print the control
                JR      C,196C,OUT-CH-3 characters and 'space'.
                RES     2,(FLAGS)   Signal 'print in K-mode'.
                CP      +CB         Jump forward if dealing
                JR      Z,196C,OUT-CH-3 with the token 'THEN'.
                CP      +3A         Jump forward unless dealing
                JR      NZ,195A,OUT-CH-1 with ':'.
                BIT     5,(FLAGX)   Jump forward to print the
                JR      NZ,1968,OUT-CH-2 ':' if in 'INPUT mode'.
                BIT     2,(FLAGS2)  Jump forward if the ':'
                JR      Z,196C,OUT-CH-3 is 'not in quotes', i.e.
                                        an inter-statement marker.
                JR      1968,OUT-CH-2   The ':' is inside quotes and can
                                        now be printed.
```

```
195A    OUT-CH-1    CP      +22                 Accept for printing all
                    JR      NZ,1968,OUT-CH-2    characters except "".
                    PUSH    AF                  Save the character code whilst
                                                changing the 'quote mode'.
                    LD      A,(FLAGS2)          Fetch FLAGS2 and flip
                    XOR     +04                 bit 2.
                    LD      (FLAGS2),A          Enter the amended value and
                    POP     AF                  restore the character code.
1968    OUT-CH-2    SET     2,(FLAGS)           Signal 'the next character is
                                                to be printed in L-mode'.
196C    OUT-CH-3    RST     0010,PRINT-A-1      The present character is
                    RET                         printed before returning.
```

Note: It is the consequence of the tests on the present character that determines whether the next character is to be "printed in 'K' or 'L' mode".
Also note how the program does not cater for ':' in REM statements.

THE 'LINE-ADDR' SUBROUTINE

For a given line number, in the HL register pair, this subroutine returns the starting address of that line or the 'first line after', in the HL register pair, and the start of the previous line in the DE register pair.
If the line number is being used the zero flag will be set. However if the 'first line after' is substituted then the zero flag is returned reset.

```
196E    LINE-ADDR   PUSH    HL                  Save the given line number.
                    LD      HL,(PROG)           Fetch the system variable
                    LD      D,H                 PROG and transfer the address
                    LD      E,L                 to the DE register pair.
```

Now enter a loop to test the line number of each line of the program against the given line number until the line number is matched or exceeded.

```
1974    LINE-AD-1   POP     BC                  The given line number.
                    CALL    1980,CP-LINES       Compare the given line number
                                                against the addressed line
                    RET     NC                  number. Return if carry reset;
                    PUSH    BC                  otherwise address the next
                    CALL    19B8,NEXT-ONE       line's number.
                    EX      DE,HL               Switch the pointers and
                    JR      1974,LINE-AD-1      jump back to consider the next
                                                line of the program.
```

THE 'COMPARE LINE NUMBERS' SUBROUTINE

The given line number in the BC register pair is matched against the addressed line number.

```
1980    CP-LINES    LD      A,(HL)              Fetch the high byte of the
                    CP      B                   addressed line number and
                    RET     NZ                  compare it. Return if they do
                                                not match.
                    INC     HL                  Next compare the low bytes.
                    LD      A,(HL)              Return with the carry flag
                    DEC     HL                  set if the addressed line
                    CP      C                   number has yet to reach the
                    RET                         given line number.
```

THE 'FIND EACH STATEMENT' SUBROUTINE

This subroutine has two distinct functions.

I. It can be used to find the 'D'th. statement in a BASIC line - returning with the HL register pair addressing the location before the start of the statement and the zero flag set.

II. Also the subroutine can be used to find a statement, if any, that starts with a given token code (in the E register).

```
1988                INC     HL              Not used.
                    INC     HL
                    INC     HL
198B    EACH-STMT   LD      (CH-ADD),HL     Set CH-ADD to the current byte.
                    LD      C,+00           Set a 'quotes off' flag.
```

Enter a loop to handle each statement in the BASIC line.

```
1990    EACH-S-1    DEC     D               Decrease 'D' and return if
                    RET     Z               the required statement has
                                            been found.
                    RST     0020,NEXT-CHAR  Fetch the next character code
                    CP      E               and jump if it does not match
                    JR      NZ,199A,EACH-S-3 the given token code.
                    AND     A               But should it match then
                    RET                     return with the carry and the
                                            zero flags both reset.
```

Now enter another loop to consider the individual characters in the line to find where the statement ends.

```
1998    EACH-S-2    INC     HL              Update the pointer and fetch
                    LD      A,(HL)          the new code.
199A    EACH-S-3    CALL    18B6,NUMBER     Step over any number.
                    LD      (CH-ADD),HL     Update CH-ADD.
                    CP      +22             Jump forward if the character
                    JR      NZ,19A5,EACH-S-4 is not a "".
                    DEC     C               Otherwise set the 'quotes flag'.
19A5    EACH-S-4    CP      +3A             Jump forward if the character
                    JR      Z,19AD,EACH-S-5 is a ':'.
                    CP      +CB             Jump forward unless the code
                    JR      NZ,19B1,EACH-S-6 is the token 'THEN'.
19AD    EACH-S-5    BIT     0,C             Read the 'quotes flag' and
                    JR      Z,1990,EACH-S-1 jump back at the end of each
                                            statement (including after
                                            'THEN').
19B1    EACH-S-6    CP      +0D             Jump back unless at the end
                    JR      NZ,1998,EACH-S-2 of a BASIC line.
                    DEC     D               Decrease the statement
                    SCF                     counter and set the carry
                    RET                     flag before returning.
```

THE 'NEXT-ONE' SUBROUTINE

This subroutine can be used to find the 'next line' in the program area or the 'next variable' in the variables area. The subroutine caters for the six different types of variable that are used in the SPECTRUM system.

```
19B8    NEXT-ONE    PUSH    HL              Save the address of the
                                            current line or variable.
                    LD      A,(HL)          Fetch the first byte.
                    CP      +40             Jump forward  if searching
                    JR      C,19D5,NEXT-O-3 for a 'next line'.
                    BIT     5,A             Jump forward if searching for
                    JR      Z,19D6,NEXT-O-4 the next string or array variable.
                    ADD     A,A             Jump forward with simple
                    JP      M,19C7,NEXT-O-1 numeric and FOR-NEXT
                                            variables.
                    CCF                     Long name numeric variables
                                            only.
19C7    NEXT-O-1    LD      BC,+0005        A numeric variable will
                    JR      NC,19CE,NEXT-O-2 occupy five locations but a
                    LD      C,+12           FOR-NEXT control variable
                                            will need eighteen locations.
19CE    NEXT-O-2    RLA                     The carry flag becomes reset
                                            for long named variables only;
                                            until the final character of the
```

```
                                                long name is reached.
                    INC     HL                  Increment the pointer and
                    LD      A,(HL)              fetch the new code.
                    JR      NC,19CE,NEXT-O-2    Jump back unless the previous
                                                code was the last code of the
                                                variable's name.
                    JR      19DB,NEXT-O-5       Now jump forward (BC =
                                                +0005 or +0012).
19D5    NEXT-O-3    INC     HL                  Step past the low byte of the
                                                line number.
19D6    NEXT-O-4    INC     HL                  Now point to the low byte
                                                of the length.
                    LD      C,(HL)              Fetch the length into the
                    INC     HL                  BC register pair.
                    LD      B,(HL)
                    INC     HL                  Allow for the inclusive byte.
```

In all cases the address of the 'next' line or variable is found.

```
19DB    NEXT-O-5    ADD     HL,BC               Point to the first byte of the
                                                'next' line or variable.
                    POP     DE                  Fetch the address of the
                                                previous one and continue into
                                                the 'difference' subroutine.
```

THE 'DIFFERENCE' SUBROUTINE

The 'length' between two 'starts' is formed in the BC register pair. The pointers are reformed but returned exchanged.

```
19DD    DIFFER      AND     A                   Prepare for a true subtraction.
                    SBC     HL,DE               Find the length from one
                    LD      B,H                 'start' to the next and pass
                    LD      C,L                 it to the BC register pair.
                    ADD     HL,DE               Reform the address and
                    EX      DE,HL               exchange them before
                    RET                         returning.
```

THE 'RECLAIMING' SUBROUTINE

The entry point RECLAIM-1 is used when the address of the first location to be reclaimed is in the DE register pair and the address of the first location to be left alone is in the HL register pair. The entry point RECLAIM-2 is used when the HL register pair points to the first location to be reclaimed and the BC register pair holds the number of the bytes that are to be reclaimed.

```
19E5    RECLAIM-1   CALL    19DD,DIFFER         Use the 'difference' subroutine
                                                to develop the appropriate
                                                values.
19E8    RECLAIM-2   PUSH    BC                  Save the number of bytes to be
                                                reclaimed.
                    LD      A,B                 All the system variable
                    CPL                         pointers above the area
                    LD      B,A                 have to be reduced by 'BC'
                    LD      A,C                 so this number is 2's
                    CPL                         complemented before the
                    LD      C,A                 pointers are altered.
                    INC     BC
                    CALL    1664,POINTERS
                    EX      DE,HL               Return the 'first location'
                    POP     HL                  address to the DE register
                    ADD     HL,DE               pair and reform the address of
                                                the first location to the left.
                    PUSH    DE                  Save the 'first location'
                    LDIR                        whilst the actual reclamation
                    POP     HL                  occurs.
                    RET                         Now return.
```

THE 'E-LINE-NO' SUBROUTINE

This subroutine is used to read the line number of the line in the editing area. If there is no line number, i.e. a direct BASIC line, then the line number is considered to be zero.
In all cases the line number is returned in the BC register pair.

19FB	E-LINE-NO	LD	HL,(E-LINE)	Pick up the pointer to the edit-line.
		DEC	HL	Set the CH-ADD to point to the
		LD	(CH-ADD),HL	location before any number.
		RST	0020,NEXT-CHAR	Pass the first code to the A register.
		LD	HL,+5C92	However before considering
		LD	(STKEND),HL	the code make the calculator's memory area a temporary calculator stack area.
		CALL	2D3B,INT-TO-FP	Now read the digits of the line number. Return zero if no number exists.
		CALL	2DA2,FP-TO-BC	Compress the line number into the BC register pair.
		JR	C,1A15,E-L-1	Jump forward if the number exceeds '65,536'.
		LD	HL,+D8F0	Otherwise test it against
		ADD	HL,BC	'10,000'.
1A15	E-L-1	JP	C,1C8A,REPORT-C	Give report C if over '9,999'.
		JP	16C5,SET-STK	Return via SET-STK that restores the calculator stack to its rightful place.

THE 'REPORT AND LINE NUMBER PRINTING' SUBROUTINE

The entry point OUT-NUM-1 will lead to the number in the BC register pair being printed. Any value over '9,999' will not however be printed correctly.
The entry point OUT-NUM-2 will lead to the number indirectly addressed by the HL register pair being printed. This time any necessary leading spaces will appear. Again the limit of correctly printed numbers is '9,999'.

1A1B	OUT-NUM-1	PUSH	DE	Save the other registers
		PUSH	HL	throughout the subroutine.
		XOR	A	Clear the A register.
		BIT	7,B	Jump forward to print a zero rather than '-2' when
		JR	NZ,1A42,OUT-NUM-4	reporting on the edit-line.
		LD	H,B	Move the number to the
		LD	L,C	HL register pair.
		LD	E,+FF	Flag 'no leading spaces'.
		JR	1A30,OUT-NUM-3	Jump forward to print the number.
1A28	OUT-NUM-2	PUSH	DE	Save the DE register pair.
		LD	D,(HL)	Fetch the number into the
		INC	HL	DE register pair and save
		LD	E,(HL)	the pointer (updated).
		PUSH	HL	
		EX	DE,HL	Move the number to the HL
		LD	E,+20	register pair and flag 'leading space are to be printed'.

Now the integer form of the number in the HL register pair is printed.

1A30	OUT-NUM-3	LD	BC,+FC18	This is '-1,000'.
		CALL	192A,OUT-SP-NO	Print a first digit.
		LD	BC,+FF9C	This is '-100'.
		CALL	192A,OUT-SP-NO	Print the second digit.
		LD	C,+F6	This is '-10'.
		CALL	192A,OUT-SP-NO	Print the third digit.

```
                    LD      A,L             Move any remaining part of
                                            the number to the A register.
1A42    OUT-NUM-4   CALL    15EF,OUT-CODE   Print the digit.
                    POP     HL              Restore the registers
                    POP     DE              before returning.
                    RET
```

BASIC LINE AND COMMAND INTERPRETATION

THE SYNTAX TABLES

i. The offset table
There is an offset value for each of the fifty BASIC commands.

			command	address				command	address
1A48	DEFB	+B1	DEF FN	1AF9	1A61	DEFB	+94	BORDER	1AF5
1A49	DEFB	+CB	CAT	1B14	1A62	DEFB	+56	CONTINUE	1AB8
1A4A	DEFB	+BC	FORMAT	1B06	1A63	DEFB	+3F	DIM	1AA2
1A4B	DEFB	+BF	MOVE	1B0A	1A64	DEFB	+41	REM	1AA5
1A4C	DEFB	+C4	ERASE	1B10	1A65	DEFB	+2B	FOR	1A90
1A4D	DEFB	+AF	OPEN #	1AFC	1A66	DEFB	+17	GO TO	1A7D
1A4E	DEFB	+B4	CLOSE #	1B02	1A67	DEFB	+1F	GO SUB	1A86
1A4F	DEFB	+93	MERGE	1AE2	1A68	DEFB	+37	INPUT	1A9F
1A50	DEFB	+91	VERIFY	1AE1	1A69	DEFB	+77	LOAD	1AE0
1A51	DEFB	+92	BEEP	1AE3	1A6A	DEFB	+44	LIST	1AAE
1A52	DEFB	+95	CIRCLE	1AE7	1A6B	DEFB	+0F	LET	1A7A
1A53	DEFB	+98	INK	1AEB	1A6C	DEFB	+59	PAUSE	1AC5
1A54	DEFB	+98	PAPER	1AEC	1A6D	DEFB	+2B	NEXT	1A98
1A55	DEFB	+98	FLASH	1AED	1A6E	DEFB	+43	POKE	1AB1
1A56	DEFB	+98	BRIGHT	1AEE	1A6F	DEFB	+2D	PRINT	1A9C
1A57	DEFB	+98	INVERSE	1AEF	1A70	DEFB	+51	PLOT	1AC1
1A58	DEFB	+98	OVER	1AF0	1A71	DEFB	+3A	RUN	1AAB
1A59	DEFB	+98	OUT	1AF1	1A72	DEFB	+6D	SAVE	1ADF
1A5A	DEFB	+7F	LPRINT	1AD9	1A73	DEFB	+42	RANDOMIZE	1AB5
1A5B	DEFB	+81	LLIST	1ADC	1A74	DEFB	+0D	IF	1A81
1A5C	DEFB	+2E	STOP	1A8A	1A75	DEFB	+49	CLS	1ABE
1A5D	DEFB	+6C	READ	1AC9	1A76	DEFB	+5C	DRAW	1AD2
1A5E	DEFB	+6E	DATA	1ACC	1A77	DEFB	+44	CLEAR	1ABB
1A5F	DEFB	+70	RESTORE	1ACF	1A78	DEFB	+15	RETURN	1A8D
1A60	DEFB	+48	NEW	1AA8	1A79	DEFB	+5D	COPY	1AD6

ii. The parameter table
For each of the fifty BASIC commands there are up to eight entries in the parameter table. These entries comprise command class details, required separators and, where appropriate, command routine addresses.

1A7A	P-LET	DEFB	+01	CLASS-01
		DEFB	+3D	'='
		DEFB	+02	CLASS-02
1A7D	P-GO-TO	DEFB	+06	CLASS-06
		DEFB	+00	CLASS-00
		DEFB	+67,+1E	GO-TO,1E67
1A81	P-IF	DEFB	+06	CLASS-06
		DEFB	+CB	'THEN'
		DEFB	+05	CLASS-05
		DEFB	+F0,+1C	IF,1CF0
1A86	P-GO-SUB	DEFB	+06	CLASS-06
		DEFB	+00	CLASS-00
		DEFB	+ED,+1E	GO-SUB,1EED
1A8A	P-STOP	DEFB	+00	CLASS-00
		DEFB	+EE,+1C	STOP,1CEE
1A8D	P-RETURN	DEFB	+00	CLASS-00
		DEFB	+23,+1F	RETURN,1F23
1A90	P-FOR	DEFB	+04	CLASS-04
		DEFB	+3D	'='
		DEFB	+06	CLASS-06
		DEFB	+CC	'TO'
		DEFB	+06	CLASS-06
		DEFB	+05	CLASS-05
		DEFB	+03,+1D	FOR,1D03

```
1A98    P-NEXT      DEFB  +04          CLASS-04
                    DEFB  +00          CLASS-00
                    DEFB  +AB,+1D      NEXT,1DAB
1A9C    P-PRINT     DEFB  +05          CLASS-05
                    DEFB  +CD,+1F      PRINT,1FCD
1A9F    P-INPUT     DEFB  +05          CLASS-05
                    DEFB  +89,+20      INPUT,2089
1AA2    P-DIM       DEFB  +05          CLASS-05
                    DEFB  +02,+2C      DIM,2C02
1AA5    P-REM       DEFB  +05          CLASS-05
                    DEFB  +B2,+1B      REM,1BB2
1AA8    P-NEW       DEFB  +00          CLASS-00
                    DEFB  +B7,+11      NEW,11B7
1AAB    P-RUN       DEFB  +03          CLASS-03
                    DEFB  +A1,+1E      RUN,1EA1
1AAE    P-LIST      DEFB  +05          CLASS-05
                    DEFB  +F9,+17      LIST,17F9
1AB1    P-POKE      DEFB  +08          CLASS-08
                    DEFB  +00          CLASS-00
                    DEFB  +80,+1E      POKE,1E80
1AB5    P-RANDOM    DEFB  +03          CLASS-03
                    DEFB  +4F,+1E      RANDOMIZE,1E4F
1AB8    P-CONT      DEFB  +00          CLASS-00
                    DEFB  +5F,+1E      CONTINUE,1E5F
1ABB    P-CLEAR     DEFB  +03          CLASS-03
                    DEFB  +AC,+1E      CLEAR,1EAC
1ABE    P-CLS       DEFB  +00          CLASS-00
                    DEFB  +6B,+0D      CLS,0D6B
1AC1    P-PLOT      DEFB  +09          CLASS-09
                    DEFB  +00          CLASS-00
                    DEFB  +DC,+22      PLOT,22DC
1AC5    P-PAUSE     DEFB  +06          CLASS-06
                    DEFB  +00          CLASS-00
                    DEFB  +3A,+1F      PAUSE,1F3A
1AC9    P-READ      DEFB  +05          CLASS-05
                    DEFB  +ED,+1D      READ,1DED
1ACC    P-DATA      DEFB  +05          CLASS-05
                    DEFB  +27,+1E      DATA,1E27
1ACF    P-RESTORE   DEFB  +03          CLASS-03
                    DEFB  +42,+1E      RESTORE,1E42
1AD2    P-DRAW      DEFB  +09          CLASS-09
                    DEFB  +05          CLASS-05
                    DEFB  +82,+23      DRAW,2382
1AD6    P-COPY      DEFB  +00          CLASS-00
                    DEFB  +AC+0E       COPY,0EAC
1AD9    P-LPRINT    DEFB  +05          CLASS-05
                    DEFB  +C9,+1F      LPRINT,1FC9
1ADC    P-LLIST     DEFB  +05          CLASS-05
                    DEFB  +F5,+17      LLIST,17F5
1ADF    P-SAVE      DEFB  +0B          CLASS-0B
1AE0    P-LOAD      DEFB  +0B          CLASS-0B
1AE1    P-VERIFY    DEFB  +0B          CLASS-0B
1AE2    P-MERGE     DEFB  +0B          CLASS-0B
1AE3    P-BEEP      DEFB  +08          CLASS-08
                    DEFB  +00          CLASS-00
                    DEFB  +F8,+03      BEEP,03F8
1AE7    P-CIRCLE    DEFB  +09          CLASS-09
                    DEFB  +05          CLASS-05
                    DEFB  +20,+23      CIRCLE,2320
1AEB    P-INK       DEFB  +07          CLASS-07
1AEC    P-PAPER     DEFB  +07          CLASS-07
1AED    P-FLASH     DEFB  +07          CLASS-07
1AEE    P-BRIGHT    DEFB  +07          CLASS-07
```

```
1AEF    P-INVERSE   DEFB  +07          CLASS-07
1AF0    P-OVER      DEFB  +07          CLASS-07
1AF1    P-OUT       DEFB  +08          CLASS-08
                    DEFB  +00          CLASS-00
                    DEFB  +7A,+1E      OUT,1E7A
1AF5    P-BORDER    DEFB  +06          CLASS-06
                    DEFB  +00          CLASS-00
                    DEFB  +94,+22      BORDER,2294
1AF9    P-DEF-FN    DEFB  +05          CLASS-05
                    DEFB  +60,+1F      DEF-FN,1F60
1AFC    P-OPEN      DEFB  +06          CLASS-06
                    DEFB  +2C          ','
                    DEFB  +0A          CLASS-0A
                    DEFB  +00          CLASS-00
                    DEFB  +36,+17      OPEN,1736
1B02    P-CLOSE     DEFB  +06          CLASS-06
                    DEFB  +00          CLASS-00
                    DEFB  +E5,+16      CLOSE,16E5
1B06    P-FORMAT    DEFB  +0A          CLASS-0A
                    DEFB  +00          CLASS-00
                    DEFB  +93,+17      CAT-ETC,1793
1B0A    P-MOVE      DEFB  +0A          CLASS-0A
                    DEFB  +2C          ','
                    DEFB  +0A          CLASS-0A
                    DEFB  +00          CLASS-00
                    DEFB  +93,+17      CAT-ETC,1793
1B10    P-ERASE     DEFB  +0A          CLASS-0A
                    DEFB  +00          CLASS-00
                    DEFB  +93,+17      CAT-ETC,1793
1B14    P-CAT       DEFB  +00          CLASS-00
                    DEFB  +93,+17      CAT-ETC,1793
```

Note: The requirements for the different command classes are as follows:

CLASS-00 - No further operands.
CLASS-01 - Used in LET. A variable is required.
CLASS-02 - Used in LET. An expression, numeric or string, must follow.
CLASS-03 - A numeric expression may follow. Zero to be used in case of default.
CLASS-04 - A single character variable must follow.
CLASS-05 - A set of items may be given.
CLASS-06 - A numeric expression must follow.
CLASS-07 - Handles colour items.
CLASS-08 - Two numeric expressions, separated by a comma, must follow.
CLASS-09 - As for CLASS-08 but colour items may precede the expressions.
CLASS-0A - A string expression must follow.
CLASS-0B - Handles cassette routines.

THE 'MAIN PARSER' OF THE BASIC INTERPRETER

The parsing routine of the BASIC interpreter is entered at LINE-SCAN when syntax is being checked, and at LINE-RUN when a BASIC program of one or more statements is to be executed.

Each statement is considered in turn and the system variable CH-ADD is used to point to each code of the statement as it occurs in the program area or the editing area.

```
1B17    LINE-SCAN   RES   7,(FLAGS)       Signal 'syntax checking'.
                    CALL  19FB,E-LINE-NO  CH-ADD is made to point to the
                                          first code after any line number.
                    XOR   A               The system variable SUBPPC
                    LD    (SUBPPC),A      is initialised to +00 and
                    DEC   A               ERR-NR to +FF.
                    LD    (ERR-NR),A
                    JR    1B29,STMT-L-1   Jump forward to consider the
                                          first statement of the line.
```

THE STATEMENT LOOP.

Each statement is considered in turn until the end of the line is reached.

```
1B28    STMT-LOOP   RST     0020,NEXT-CHAR      Advance CH-ADD along the line.
1B29    STMT-L-1    CALL    16BF,SET-WORK       The work space is cleared.
                    INC     (SUBPPC)            Increase SUBPPC on each
                                                passage around the loop.
                    JP      M,1C8A,REPORT-C     But only '127' statements are
                                                allowed in a single line.
                    RST     0018,GET-CHAR       Fetch a character.
                    LD      B,+00               Clear the register for later.
                    CP      +0D                 Is the character a 'carriage
                    JR      Z,1BB3,LINE-END     return'; jump if it is.
                    CP      +3A                 Go around the loop again if
                    JR      Z,1B28,STMT-LOOP    it is a ':'.
```

A statement has been identified so, first, its initial command is considered.

```
                    LD      HL,+1B76            Pre-load the machine stack
                    PUSH    HL                  with the return address
                                                - STMT-RET.
                    LD      C,A                 Save the command temporarily
                    RST     0020,NEXT-CHAR      in the C register whilst
                    LD      A,C                 CH-ADD is advanced again.
                    SUB     +CE                 Reduce the command's code by
                                                +CE; giving the range +00 to
                                                +31 for the fifty commands.
                    JP      C,1C8A,REPORT-C     Give the appropriate error if
                                                not a command code.
                    LD      C,A                 Move the command code to the
                                                BC register pair (B holds +00).
                    LD      HL,+1A48            The base address of the syntax
                                                offset table.
                    ADD     HL,BC               The required offset is passed to
                    LD      C,(HL)              the C register and used to
                    ADD     HL,BC               compute the base address for
                                                the command's entries in the
                                                parameter table.
                    JR      1B55,GET-PARAM      Jump forward into the scanning
                                                loop with this address.
```

Each of the command class routines applicable to the present command are executed in turn. Any required separators are also considered.

```
1B52    SCAN-LOOP   LD      HL,(T-ADDR)         The temporary pointer to the
                                                entries in the parameter table.
1B55    GET-PARAM   LD      A,(HL)              Fetch each entry in turn.
                    INC     HL                  Update the pointer to the
                    LD      (T-ADDR),HL         entries for the next pass.
                    LD      BC,+1B52            Pre-load the machine stack
                    PUSH    BC                  with the return address -
                                                SCAN-LOOP.
                    LD      C,A                 Copy the entry to the C register
                                                for later.
                    CP      +20                 Jump forward if the entry is
                    JR      NC,1B6F,SEPARATOR   a 'separator'.
                    LD      HL,+1C01            The base address of the
                                                'command class' table.
                    LD      B,+00               Clear the B register and
                    ADD     HL,BC               index into the table.
                    LD      C,(HL)              Fetch the offset and compute
                    ADD     HL,BC               the starting address of the
                                                required command class routine
                    PUSH    HL                  Push the address on to the
                                                machine stack.
```

```
                RST     0018,GET-CHAR       Before making an indirect
                DEC     B                   jump to the command class
                RET                         routine pass the command code
                                            to the A register and set the B
                                            register to +FF.
```

THE 'SEPARATOR' SUBROUTINE

The report - 'Nonsense in BASIC is given if the required separator is not present. But note that when syntax is being checked the actual report does not appear on the screen - only the 'error marker'.

```
1B6F    SEPARATOR   RST     0018,GET-CHAR       The current character is
                    CP      C                   fetched and compared to the
                                                entry in the parameter table.
                    JP      NZ,1C8A,REPORT-C    Give the error report if there
                                                is not a match.
                    RST     0020,NEXT-CHAR      Step past a correct character
                    RET                         and return.
```

THE 'STMT-RET' SUBROUTINE

After the correct interpretation of a statement a return is made to this entry point.

```
1B76    STMT-RET    CALL    1F54,BREAK-KEY      The BREAK key is tested after
                                                every statement.
                    JR      C,1B7D,STMT-R-1     Jump forward unless it has
                                                been pressed.
```

Report L - 'BREAK into program'

```
1B7B    REPORT-L    RST     0008,ERROR-1        Call the error handling
                    DEFB    +14                 routine.
```

Continue here as the BREAK key was not pressed.

```
1B7D    STMT-R-1    BIT     7,(NSPPC)           Jump forward if there is not
                    JR      NZ,1BF4,STMT-NEXT   a 'jump' to be made.
                    LD      HL,(NEWPPC)         Fetch the 'new line' number
                    BIT     7,H                 and jump forward unless dealing
                    JR      Z,1B9E,LINE-NEW     with a further statement in the
                                                editing area.
```

THE 'LINE-RUN' ENTRY POINT

This entry point is used wherever a line in the editing area is to be 'run'. In such a case the syntax/run flag (bit 7 of FLAGS) will be set.

The entry point is also used in the syntax checking of a line in the editing area that has more than one statement (bit 7 of FLAGS will be reset).

```
1B8A    LINE-RUN    LD      HL,+FFFE            A line in the editing area
                    LD      (PPC),HL            is considered as line '-2'.
                    LD      HL,(WORKSP)         Make HL point to the end
                    DEC     HL                  marker of the editing area
                    LD      DE,(E-LINE)         and DE to the location before
                    DEC     DE                  the start of that area.
                    LD      A,(NSPPC)           Fetch the number of the next
                                                statement to be handled
                    JR      1BD1,NEXT-LINE      before jumping forward.
```

THE 'LINE-NEW' SUBROUTINE

There has been a jump in the program and the starting address of the new line has to be found.

```
1B9E    LINE-NEW    CALL    196E,LINE-ADDR      The starting address of the line,
                                                or the 'first line after' is found.
                    LD      A,(NSPPC)           Collect the statement number.
                    JR      Z,1BBF,LINE-USE     Jump forward if the required
                    AND     A                   line was found; otherwise
```

```
                    JR      NZ,1BEC,REPORT-N    check the validity of the state-
                                                ment number - must be zero.
                    LD      B,A                 Also check that the 'first
                    LD      A,(HL)              line after' is not after the
                    AND     +C0                 actual 'end of program'.
                    LD      A,B
                    JR      Z,1BBF,LINE-USE     Jump forward with valid
                                                addresses; otherwise signal the
                                                error 'OK'.
```

Report 0 - 'OK'

```
1BB0    REPORT-0    RST     0008,ERROR-1        Use the error handling
                    DEFB    +FF                 routine.
```

Note: Obviously not an error in the normal sense — but rather a jump past the program.

THE 'REM' COMMAND ROUTINE

The return address to STMT-RET is dropped which has the effect of forcing the rest of the line to be ignored.

```
1BB2    REM         POP     BC                  Drop the address - STMT-RET.
```

THE 'LINE-END' ROUTINE

If checking syntax a simple return is made but when 'running' the address held by NXTLIN has to be checked before it can be used.

```
1BB3    LINE-END    CALL    2530,SYNTAX-Z       Return if syntax is being
                    RET     Z                   checked; otherwise fetch
                    LD      HL,(NXTLIN)         the address in NXTLIN.
                    LD      A,+C0               Return also if the address is
                    AND     (HL)                after the end of the program
                    RET     NZ                  - the 'run' is finished.
                    XOR     A                   Signal 'statement zero' before
                                                proceeding.
```

THE 'LINE-USE' ROUTINE

This short routine has three functions; i. Change statement zero to statement '1'; ii. Find the number of the new line and enter it into PPC; & iii. Form the address of the start of the line after.

```
1BBF    LINE-USE    CP      +01                 Statement zero becomes
                    ADC     A,+00               statement '1'
                    LD      D,(HL)              The line number of the line
                    INC     HL                  to be used is collected and
                    LD      E,(HL)              passed to PPC.
                    LD      (PPC),DE
                    INC     HL                  Now find the 'length'
                    LD      E,(HL)              of the line.
                    INC     HL
                    LD      D,(HL)
                    EX      DE,HL               Switch over the values.
                    ADD     HL,DE               Form the address of the start
                    INC     HL                  of the line after in HL and the
                                                location before the 'next' line's
                                                first character in DE.
```

THE 'NEXT-LINE' ROUTINE

On entry the HL register pair points to the location after the end of the 'next' line to be handled and the DE register pair to the location before the first character of the line. This applies to lines in the program area and also to a line in the editing area - where the next line will be the same line again whilst there are still statements to be interpreted.

```
1BD1    NEXT-LINE   LD      (NXTLIN),HL         Set NXTLIN for use once the
                                                current line has been completed.
                    EX      DE,HL               As usual CH-ADD points to the
```

```
                LD      (CH-ADD),HL     location before the first
                                        character to be considered.
                LD      D,A             The statement number is
                                        fetched.
                LD      E,+00           The E register is cleared in case
                                        EACH-STMT is used.
                LD      (NSPPC),+FF     Signal 'no jump'.
                DEC     D               The statement number minus
                LD      (SUBPPC),D      one goes into SUBPPC.
                JP      Z,1B28,STMT-LOOP A first statement can now be
                                        considered.
                INC     D               However for later statements
                CALL    198B,EACH-STMT  the 'starting address' has to be
                                        found.
                JR      Z,1BF4,STMT-NEXT Jump forward unless the state-
                                        ment does not exist.
```

Report N - 'Statement lost'

```
1BEC  REPORT-N  RST     0008,ERROR-1    Call the error handling
                DEFB    +16             routine.
```

THE 'CHECK-END' SUBROUTINE

This is an important routine and is called from many places in the monitor program when the syntax of the edit-line is being checked. The purpose of the routine is to give an error report if the end of a statement has not been reached and to move on to the next statement if the syntax is correct.

```
1BEE  CHECK-END CALL    2530,SYNTAX-Z   Do not proceed unless
                RET     NZ              checking syntax.
                POP     BC              Drop the addresses of
                POP     BC              SCAN-LOOP & STMT-RET
                                        before continuing into
                                        STMT-NEXT.
```

THE 'STMT-NEXT' ROUTINE

If the present character is a 'carriage return' then the 'next statement' is on the 'next line'; if ' : ' it is on the same line; but if any other character is found then there is an error in syntax.

```
1BF4  STMT-NEXT RST     0018,GET-CHAR   Fetch the present character.
                CP      +0D             Consider the 'next line' if
                JR      Z,1BB3,LINE-END it is a 'carriage return'.
                CP      +3A             Consider the 'next statement'
                JP      Z,1B28,STMT-LOOP if it is a ' : '.
                JP      1C8A,REPORT-C   Otherwise there has been a
                                        syntax error.
```

THE 'COMMAND CLASS' TABLE

address	offset	class number	address	offset	class number
1C01	0F	CLASS-00-1C10	1C07	7B	CLASS-06,1C82
1C02	1D	CLASS-01,1C1F	1C08	8E	CLASS-07,1C96
1C03	4B	CLASS-02,1C4E	1C09	71	CLASS-08,1C7A
1C04	09	CLASS-03,1C0D	1C0A	B4	CLASS-09,1CBE
1C05	67	CLASS-04,1C6C	1C0B	81	CLASS-0A,1C8C
1C06	0B	CLASS-05,1C11	1C0C	CF	CLASS-0B,1CDB

THE 'COMMAND CLASSES - 00, 03 & 05'

The commands of class-03 may, or may not, be followed by a number. e.g. RUN & RUN 200.

```
1C0D  CLASS-03  CALL    1CDE,FETCH-NUM  A number is fetched but zero
                                        is used in cases of default.
```

The commands of class-00 must not have any operands. e.g. COPY & CONTINUE.

```
1C10    CLASS-00    CP      A                   Set the zero flag for later.
```

The commands of class-05 may be followed by a set of items. e.g. PRINT & PRINT "222".

```
1C11    CLASS-05    POP     BC                  In all cases drop the address
                                                - SCAN-LOOP.
                    CALL    Z,1BEE,CHECK-END    If handling commands of classes
                                                00 & 03 AND syntax is being
                                                checked move on now to
                                                consider the next statement.
                    EX      DE,HL               Save the line pointer in the DE
                                                register pair.
```

THE 'JUMP-C-R' ROUTINE

After the command class entries and the separator entries in the parameter table have been considered the jump to the appropriate command routine is made.

```
1C16    JUMP-C-R    LD      HL,(T-ADDR)         Fetch the pointer to the
                    LD      C,(HL)              entries in the parameter table
                    INC     HL                  and fetch the address of the
                    LD      B,(HL)              required command routine.
                    EX      DE,HL               Exchange the pointers back
                    PUSH    BC                  and make an indirect jump
                    RET                         to the command routine.
```

THE 'COMMAND CLASSES - 01, 02 & 04'

These three command classes are used by the variable handling commands - LET, FOR & NEXT and indirectly by READ & INPUT.

Command class 01 is concerned with the identification of the variable in a LET, READ or INPUT statement.

```
1C1F    CLASS-01    CALL    28B2,LOOK-VARS      Look in the variables area to
                                                determine whether or not
                                                the variable has been used already.
```

THE 'VARIABLE IN ASSIGNMENT' SUBROUTINE

This subroutine develops the appropriate values for the system variables DEST & STRLEN.

```
1C22    VAR-A-1     LD      (FLAGX),+00         Initialise FLAGX to +00.
                    JR      NC,1C30,VAR-A-2     Jump forward if the variable
                                                has been used before.
                    SET     1,(FLAGX)           Signal 'a new variable'.
                    JR      NZ,1C46,VAR-A-3     Give an error if trying to use
                                                an 'undimensioned array'.
```

Report 2 - Variable not found

```
1C2E    REPORT-2    RST     0008,ERROR-1        Call the error handling
                    DEFB    +01                 routine.
```

Continue with the handling of existing variables.

```
1C30    VAR-A-2     CALL    Z,2996,STK-VARS     The parameters of simple string
                                                variables and all array variables
                                                are passed to the calculator
                                                stack. (STK-VARS will 'slice' a
                                                string if required.)
                    BIT     6,(FLAGS)           Jump forward if handling a
                    JR      NZ,1C46,VAR-A-3     numeric variable.
                    XOR     A                   Clear the A register.
                    CALL    2530,SYNTAX-Z       The parameters of the string of
                    CALL    NZ,2BF1,STK-FETCH   string array variable are fetched
                                                unless syntax is being checked.
                    LD      HL,+5C71            This is FLAGX.
```

```
                OR      (HL)                Bit 0 is set only when handling
                LD      (HL),A              complete simple strings' thereby
                                            signalling 'old copy to be
                                            deleted'.
                EX      DE,HL               HL now points to the string or
                                            the element of the array.
```

The pathways now come together to set STRLEN & DEST as required. For all numeric variables and 'new' string & string array variables STRLEN-lo holds the 'letter' of the variable's name. But for 'old' string & string array variables whether 'sliced' or complete it holds the 'length' in 'assignment'.

```
1C46    VAR-A-3     LD      (STRLEN),BC         Set STRLEN as required.
```

DEST holds the address for the 'destination of an 'old' variable but in effect the 'source' for a 'new' variable.

```
                    LD      (DEST),HL           Set DEST as required and
                    RET                         return.
```

Command class 02 is concerned with the actual calculation of the value to be assigned in a LET statement.

```
1C4E    CLASS-02    POP     BC                  The address - SCAN-LOOP is
                                                dropped.
                    CALL    1C56,VAL-FET-1      The assignment is made.
                    CALL    1BEE,CHECK-END      Move on to the next statement
                                                either via CHECK-END if
                    RET                         checking syntax, or STMT-RET
                                                if in 'run-time'.
```

THE 'FETCH A VALUE' SUBROUTINE

This subroutine is used by LET, READ & INPUT statements to first evaluate and then assign values to the previously designated variable.

The entry point VAL-FET-1 is used by LET & READ and considers FLAGS whereas the entry point VAL-FET-2 is used by INPUT and considers FLAGX.

```
1C56    VAL-FET-1   LD      A,(FLAGS)           Use FLAGS.
1C59    VAL-FET-2   PUSH    AF                  Save FLAGS or FLAGX.
                    CALL    24FB,SCANNING       Evaluate the next expression.
                    POP     AF                  Fetch the old FLAGS or FLAGX.
                    LD      D,(FLAGS)           Fetch the new FLAGS.
                    XOR     D                   The nature - numeric or string
                    AND     +40                 of the variable and the
                                                expression must match.
                    JR      NZ,1C8A,REPORT-C    Give report C if they do not.
                    BIT     7,D                 Jump forward to make the
                    JP      NZ,2AFF,LET         actual assignment unless
                                                checking syntax when simply
                    RET                         return.
```

THE 'COMMAND CLASS 04' ROUTINE

The command class 04 entry point is used by FOR & NEXT statements.

```
1C6C    CLASS-04    CALL    28B2,LOOK-VARS      Look in the variables area for
                                                the variable being used.
                    PUSH    AF                  Save the AF register pair whilst
                    LD      A,C                 the discriminator byte is tested
                    OR      +9F                 to ensure that the variable
                    INC     A                   is a FOR-NEXT control
                    JR      NZ,1C8A,REPORT-C    variable.
                    POP     AF                  Restore the flags register and
                    JR      1C22,VAR-A-1        jump back to make the variable
                                                that has been found the
                                                'variable in assignment'.
```

THE 'EXPECT NUMERIC/STRING EXPRESSIONS' SUBROUTINE

There is a series of short subroutines that are used to fetch the result of evaluating the next expression. The result from a single expression is returned as a 'last value' on the calculator stack.

The entry point NEXT-2NUM is used when CH-ADD needs updating to point to the start of the first expression.

1C79	NEXT-2NUM	RST	0020,NEXT-CHAR	Advance CH-ADD.

The entry point EXPT-2NUM (EQU. CLASS-08) allows for two numeric expressions, separated by a comma, to be evaluated.

1C7A	EXPT-2NUM (CLASS-08)	CALL	1C82,EXPT-1NUM	Evaluate each expression in turn - so evaluate the first.
		CP	+2C	Give an error report if the
		JR	NZ,1C8A	separator is not a comma.
		RST	0020,NEXT-CHAR	Advance CH-ADD.

The entry point EXPT-1NUM (EQU. CLASS-06) allows for a single numeric expression to be evaluated.

1C82	EXPT-1NUM (CLASS-06)	CALL	24FB,SCANNING	Evaluate the next expression.
		BIT	6,(FLAGS)	Return as long as the result was
		RET	NZ	numeric; otherwise it is an error.

Report C - Nonsense in BASIC

1C8A	REPORT-C	RST	0008,ERROR-1	Call the error handling
		DEFB	+0B	routine.

The entry point EXPT-EXP (EQU. CLASS-0A) allows for a single string expression to be evaluated.

1C8C	EXPT-EXP (CLASS-0A)	CALL	24FB,SCANNING	Evaluate the next expression.
		BIT	6,(FLAGS)	This time return if the result
		RET	Z	indicates a string; otherwise
		JR	1C8A,REPORT-C	give an error report.

THE 'SET PERMANENT COLOURS' SUBROUTINE (EQU. CLASS-07)

This subroutine allows for the current temporary colours to be made permanent. As command class 07 it is in effect the command routine for the six colour item commands.

1C96	PERMS (CLASS-07)	BIT	7,(FLAGS)	The syntax/run flag is read.
		RES	0,(TV-FLAG)	Signal 'main screen'.
		CALL	NZ,0D4D,TEMPS	Only during a 'run' call TEMPS to ensure the temporary colours are the main screen colours.
		POP	AF	Drop the return address - SCAN-LOOP.
		LD	A,(T-ADDR)	Fetch the low byte of T-ADDR and subtract +13 to give the
		SUB	+13	range +D9 to +DE which are the token codes for INK to OVER.
		CALL	21FC,CO-TEMP-4	Jump forward to change the temporary colours as directed by the BASIC statement.
		CALL	1BEE,CHECK-END	Move on to the next statement if checking syntax.
		LD	HL,(ATTR-T)	Now the temporary colour
		LD	(ATTR-P),HL	values are made permanent (both ATTR-P & MASK-P).
		LD	HL,+5C91	This is P-FLAG; and that too
		LD	A,(HL)	has to be considered.

The following instructions cleverly copy the even bits of the supplied byte to the odd bits. In effect making the permanent bits the same as the temporary ones.

```
                RLCA                    Move the mask leftwards.
                XOR     (HL)            Impress onto the mask
                AND     +AA             only the even bits of the
                XOR     (HL)            other byte.
                LD      (HL),A          Restore the result.
                RET
```

THE 'COMMAND CLASS 09' ROUTINE

This routine is used by PLOT, DRAW & CIRCLE statements in order to specify the default conditions of 'FLASH 8; BRIGHT 8; PAPER 8;' that are set up before any embedded colour items are considered.

```
1CBE    CLASS-09    CALL    2530,SYNTAX-Z   Jump forward if
                    JR      Z,1CD6,CL-09-1  checking syntax.
                    RES     0,(TV-FLAG)     Signal 'main screen'.
                    CALL    0D4D,TEMPS      Set the temporary colours for
                                            the main screen.
                    LD      HL,+5C90        This is MASK-T.
                    LD      A,(HL)          Fetch its present value but
                    OR      +F8             keep only its INK part
                                            'unmasked'.
                    LD      (HL),A          Restore the value which now
                                            indicates 'FLASH 8; BRIGHT 8;
                                            PAPER 8;'.
                    RES     6,(P-FLAG)      Also ensure NOT 'PAPER 9'.
                    RST     0018,GET-CHAR   Fetch the present character
                                            before continuing to deal with
                                            embedded colour items.
1CD6    CL-09-1     CALL    21E2,CO-TEMP    Deal with the locally dominant
                                            colour items.
                    JR      1C7A,EXPT-2NUM  Now get the first two operands
                                            for PLOT, DRAW or CIRCLE.
```

THE 'COMMAND CLASS 0B' ROUTINE

This routine is used by SAVE, LOAD, VERIFY & MERGE statements.

```
1CDB    CLASS-0B    JP      0605,SAVE-ETC   Jump to the cassette
                                            handling routine.
```

THE 'FETCH A NUMBER' SUBROUTINE

This subroutine leads to a following numeric expression being evaluated but zero being used instead if there is no expression.

```
1CDE    FETCH-NUM   CP      +0D             Jump forward if at the end
                    JR      Z,1CE6,USE-ZERO of a line.
                    CP      +3A             But jump to EXPT-1NUM unless
                    JR      NZ,1C82,EXPT-1NUM at the end of a statement.
```

The calculator is now used to add the value zero to the calculator stack.

```
1CE6    USE-ZERO    CALL    2530,SYNTAX-Z   Do not perform the operation
                    RET     Z               if syntax is being checked.
                    RST     0028,FP-CALC    Use the calculator.
                    DEFB    +A0,stk-zero    The 'last value' is now zero.
                    DEFB    +38,end-calc
                    RET                     Return with zero added to the
                                            stack.
```

THE COMMAND ROUTINES

The section of the 16K monitor program from 1CEE to 23FA contains most of the command routines of the BASIC interpreter.

THE 'STOP' COMMAND ROUTINE

The command routine for STOP contains only a call to the error handling routine.

```
1CEE    STOP        RST     0008,ERROR-1        Call the error handling
        (REPORT-9)  DEFB    +08                 routine.
```

THE 'IF' COMMAND ROUTINE

On entry the value of the expression between the IF and the THEN is the 'last value' on the calculator stack. If this is logically true then the next statement is considered; otherwise the line is considered to have been finished.

```
1CF0    IF          POP     BC                  Drop the return address
                                                - STMT-RET.
                    CALL    2530,SYNTAX-Z       Jump forward if checking
                    JR      Z,1D00,IF-1         syntax.
```

Now use the calculator to 'delete' the last value on the calculator stack but leave the DE register pair addressing the first byte of the value.

```
                    RST     0028,FP-CALC        Use the calculator.
                    DEFB    +02,delete          The present 'last value' is
                    DEFB    +38,end-calc        deleted.
                    EX      DE,HL               Make HL point to the first
                    CALL    34E9,TEST-ZERO      byte and call TEST-ZERO.
                    JP      C,1BB3,LINE-END     If the value was 'FALSE' jump
                                                to the next line.
1D00    IF-1        JP      1B29,STMT-L-1       But if 'TRUE' jump to the next
                                                statement (after the THEN).
```

THE 'FOR' COMMAND ROUTINE

This command routine is entered with the VALUE and the LIMIT of the FOR statement already on the top of the calculator stack.

```
1D03    FOR         CP      +CD                 Jump forward unless a 'STEP'
                    JR      NZ,1D10,F-USE-1     is given.
                    RST     0020,NEXT-CHAR      Advance CH-ADD and fetch the
                    CALL    1C82,EXPT-1NUM      value of the STEP.
                    CALL    1BEE,CHECK-END      Move on to the next statement
                    JR      1D16,F-REORDER      if checking syntax; otherwise
                                                jump forward.
```

There has not been a STEP supplied so the value '1' is to be used.

```
1D10    F-USE-1     CALL    1BEE,CHECK-END      Move on to the next statement
                                                if checking syntax; otherwise
                    RST     0028,FP-CALC        use the calculator to place a '1'
                    DEFB    +A1,stk-one         on the calculator stack.
                    DEFB    +38,end-calc
```

The three values on the calculator stack are the VALUE (v), the LIMIT (l) and the STEP (s). These values now have to be manipulated.

```
1D16    F-REORDER   RST     0028,FP-CALC        v, l, s
                    DEFB    +C0,st-mem-0        v, l, s (mem-0 = s)
                    DEFB    +02,delete          v, l
                    DEFB    +01,exchange        l, v
                    DEFB    +E0,get-mem-0       l, v, s
                    DEFB    +01,exchange        l, s, v
                    DEFB    +38,end-calc
```

A FOR control variable is now established and treated as a temporary calculator memory area.

```
                    CALL    2AFF,LET            The variable is found, or created
                                                if needed (v is used).
                    LD      (MEM),HL            Make it a 'memory area'.
```

The variable that has been found may be a simple numeric variable using only six locations in which case it will need extending.

```
                DEC     HL              Fetch the variable's single
                LD      A,(HL)          character name.
                SET     7,(HL)          Ensure bit 7 of the name is set.
                LD      BC,+0006        It will have six locations at least.
                ADD     HL,BC           Make HL point after them.
                RLCA                    Rotate the name and jump if
                JR      C,1D34,F-L&S    it was already a FOR variable.
                LD      C,+0D           Otherwise create thirteen
                CALL    1655,MAKE-ROOM  more locations.
                INC     HL              Again make HL point to the
                                        LIMIT position.
```

The initial values for the LIMIT and the STEP are now added.

```
1D34    F-L&S   PUSH    HL              The pointer is saved.
                RST     0028,FP-CALC    l, s
                DEFB    +02,delete      l
                DEFB    +02,delete      -
                DEFB    +38,end-calc    DE still points to 'l'.
                POP     HL              The pointer is restored and
                EX      DE,HL           both pointers exchanged.
                LD      C,+0A           The ten bytes of the LIMIT
                LDIR                    and the STEP are moved.
```

The looping line number and statement number are now entered.

```
                LD      HL,(PPC)        The current line number.
                EX      DE,HL           Exchange the registers before
                LD      (HL),E          adding the line number to the
                INC     HL              FOR control variable.
                LD      (HL),D
                LD      D,(SUBPPC)      The looping statement is
                INC     D               always the next statement -
                INC     HL              whether it exists or not.
                LD      (HL),D
```

The NEXT-LOOP subroutine is called to test the possibility of a 'pass' and a return is made if one is possible; otherwise the statement after for FOR - NEXT loop has to be identified.

```
                CALL    1DDA,NEXT-LOOP  Is a 'pass' possible?
                RET     NC              Return now if it is.
                LD      B,(STRLEN-lo)   Fetch the variable's name.
                LD      HL,(PPC)        Copy the present line number
                LD      (NEWPPC),HL     to NEWPPC.
                LD      A,(SUBPPC)      Fetch the current statement
                NEG                     number and two's complement it.
                LD      D,A             Transfer the result to the D
                                        register.
                LD      HL,(CH-ADD)     Fetch the current value of
                                        CH-ADD.
                LD      E,+F3           The search will be for 'NEXT'.
```

Now a search is made in the program area, from the present point onwards, for the first occurrence of NEXT followed by the correct variable.

```
1D64    F-LOOP  PUSH    BC              Save the variable's name.
                LD      BC,(NXTLIN)     Fetch the current value of
                                        NXTLIN.
                CALL    1D86,LOOK-PROG  The program area is now
                                        searched and BC will change
                                        with each new line examined.
                LD      (NXTLIN),BC     Upon return save the pointer.
                POP     BC              Restore the variable's name.
                JR      C,1D84,REPORT-I If there are no further NEXTs
                                        then give an error.
```

```
                RST     0020,NEXT-CHAR  Advance past the NEXT that
                                        was found.
                OR      +20             Allow for upper and lower
                CP      B               case letters before the new
                                        variable name is tested.
                JR      Z,1D7C,F-FOUND  Jump forward if it matches.
                RST     0020,NEXT-CHAR  Advance CH-ADD again and
                JR      1D64,F-LOOP     jump back if not the correct
                                        variable.
```

NEWPPC holds the line number of the line in which the correct NEXT was found. Now the statement number has to be found and stored in NSPPC.

```
1D7C  F-FOUND   RST     0020,NEXT-CHAR  Advance CH-ADD.
                LD      A,+01           The statement counter in the
                SUB     D               D register counted statements
                                        back from zero so it has to
                                        be subtracted from '1'.
                LD      (NSPPC),A       The result is stored.
                RET                     Now return - to STMT-RET.
```

REPORT I - FOR without NEXT

```
1D84  REPORT-I  RST     0008,ERROR-1    Call the error handling
                DEFB    +11             routine.
```

THE 'LOOK-PROG' SUBROUTINE

This subroutine is used to find occurrences of either DATA, DEF FN or NEXT. On entry the appropriate token code is in the E register and the HL register pair points to the start of the search area.

```
1D86  LOOK-PROG LD      A,(HL)          Fetch the present character.
                CP      +3A             Jump forward if it is a ' : '
                JR      Z,1DA3,LOOK-P-2 which will indicate there are
                                        more statements in the present
                                        line.
```

Now a loop is entered to examine each further line in the program.

```
1D8B  LOOK-P-1  INC     HL              Fetch the high byte of the
                LD      A,(HL)          line number and return with
                AND     +CO             carry set if there are no
                SCF                     further lines in the program.
                RET     NZ
                LD      B,(HL)          The line number is fetched
                INC     HL              and passed to NEWPPC.
                LD      C,(HL)
                LD      (NEWPPC),BC
                INC     HL              Then the length is collected.
                LD      C,(HL)
                INC     HL
                LD      B,(HL)
                PUSH    HL              The pointer is saved whilst
                ADD     HL,BC           the address of the end of the
                LD      B,H             line is formed in the BC
                LD      C,L             register pair.
                POP     HL              The pointer is restored.
                LD      D,+00           Set the statement counter to
                                        zero.
1DA3  LOOK-P-2  PUSH    BC              The end-of-line pointer is
                CALL    198B,EACH-STMT  saved whilst the statements
                POP     BC              of the line are examined.
                RET     NC              Make a return if there was
                JR      1D8B,LOOK-P-1   an 'occurrence'; otherwise
                                        consider the next line.
```

THE 'NEXT' COMMAND ROUTINE

The 'variable in assignment' has already been determined (see CLASS-04,1C6C); and it remains to change the VALUE as required.

```
1DAB    NEXT        BIT     1,(FLAGX)           Jump to give the error report
                    JP      NZ,1C2E,REPORT-2    if the variable was not found.
                    LD      HL,(DEST)           The address of the variable
                    BIT     7,(HL)              is fetched and the name
                    JR      Z,1DD8,REPORT-1     tested further.
```

Next the variable's VALUE and STEP are manipulated by the calculator.

```
                    INC     HL                  Step past the name.
                    LD      (MEM),HL            Make the variable a
                                                temporary 'memory area'.
                    RST     0028,FP-CALC        -
                    DEFB    +E0,get-mem-0       v
                    DEFB    +E2,get-mem-2       v, s
                    DEFB    +0F,addition        v+s
                    DEFB    +C0,st-mem-0        v+s
                    DEFB    +02,delete          -
                    DEFB    +38,end-calc        -
```

The result of adding the VALUE and the STEP is now tested against the LIMIT by calling NEXT-LOOP.

```
                    CALL    1DDA,NEXT-LOOP      Test the new VALUE against
                                                the LIMIT
                    RET     C                   Return now if the FOR-NEXT
                                                loop has been completed.
```

Otherwise collect the 'looping' line number and statement.

```
                    LD      HL,(MEM)            Find the address of the
                    LD      DE,+000F            low byte of the looping
                    ADD     HL,DE               line number.
                    LD      E,(HL)              Now fetch this line number.
                    INC     HL
                    LD      D,(HL)
                    INC     HL
                    LD      H,(HL)              Followed by the statement
                                                number.
                    EX      DE,HL               Exchange the numbers before
                    JP      1E73,GO-TO-2        jumping forward to treat them
                                                as the destination line of a
                                                GO TO command.
```

Report 1 - NEXT without FOR

```
1DD8    REPORT-1    RST     0008,ERROR-1        Call the error handling
                    DEFB    +00                 routine.
```

THE 'NEXT-LOOP SUBROUTINE

This subroutine is used to determine whether the LIMIT has been exceeded by the present VALUE. Note has to be taken of the sign of the STEP.

The subroutine returns the carry flag set if the LIMIT is exceeded.

```
1DDA    NEXT-LOOP   RST     0028,FP-CALC        -
                    DEFB    +E1,get-mem-1       l
                    DEFB    +E0,get-mem-0       l, v
                    DEFB    +E2,get-mem-2       l, v, s
                    DEFB    +36,less-0          l, v,(1/0)
                    DEFB    +00,jump-true       l, v,(1/0)
                    DEFB    +02,to NEXT-1       l, v,(1/0)
                    DEFB    +01,exchange        v, l
1DE2    NEXT-1      DEFB    +03,subtract        v-l or l-v
                    DEFB    +37,greater-0       (1/0)
                    DEFB    +00,jump-true       (1/0)
```

```
                DEFB    +04,to NEXT-2       -
                DEFB    +38,end-calc        -
                AND     A                   Clear the carry flag and
                RET                         return - loop is possible.
```

However if the loop is impossible the carry flag has to be set.

```
1DE9  NEXT-2    DEFB    +38,end-calc        -
                SCF                         Set the carry flag and
                RET                         return.
```

THE 'READ' COMMAND ROUTINE

The READ command allows for the reading of a DATA list and has an effect similar to a series of LET statements.

Each assignment within a single READ statement is dealt with in turn. The system variable X-PTR is used as a storage location for the pointer to the READ statement whilst CH-ADD is used to step along the DATA list.

```
1DEC  READ-3    RST     0020,NEXT-CHAR      Come here on each pass, after
                                            the first, to move along the
                                            READ statement.
1DED  READ      CALL    1C1F,CLASS-01       Consider whether the variable
                                            has been used before; find
                                            the existing entry if it has.
                CALL    2530,SYNTAX-Z       Jump forward if checking
                JR      Z,1E1E,READ-2       syntax.
                RST     0018,GET-CHAR       Save the current pointer
                LD      (X-PTR),HL          CH-ADD in X-PTR.
                LD      HL,(DATADD)         Fetch the current DATA list
                LD      A,(HL)              pointer and jump forward
                CP      +2C                 unless a new DATA statement
                JR      Z,1E0A,READ-1       has to be found.
                LD      E,+E4               The search is for 'DATA'.
                CALL    1D86,LOOK-PROG      Jump forward if the search is
                JR      NC,1E0A,READ-1      successful.
```

Report E - Out of DATA

```
1E08  REPORT-E  RST     0008,ERROR-1        Call the error handling
                DEFB    +0D                 routine.
```

Continue - picking up a value from the DATA list.

```
1E0A  READ-1    CALL    0077,TEMP-PTR1      Advance the pointer along the
                                            DATA list and set CH-ADD.
                CALL    1C56,VAL-FET-1      Fetch the value and assign it
                                            to the variable.
                RST     0018,GET-CHAR       Fetch the current value of
                LD      (DATADD),HL         CH-ADD and store it in
                                            DATADD.
                LD      HL,(X-PTR)          Fetch the pointer to the
                LD      (X-PTR-hi),+00      READ statement and clear
                                            X-PTR.
                CALL    0078,TEMP-PTR2      Make CH-ADD once again point
                                            to the READ statement.
1E1E  READ-2    RST     0018,GET-CHAR       GET the present character and
                CP      +2C                 see if it is a ','.
                JR      Z,1DEC,READ-3       If it is then jump back as
                                            there are further items;
                CALL    1BEE,CHECK-END      otherwise return either via
                RET                         CHECK-END (if checking
                                            syntax) or the RET instruction
                                            (to STMT-RET).
```

THE 'DATA' COMMAND ROUTINE

During syntax checking a DATA statement is checked to ensure that it contains a series of valid expressions, separated by commas. But in 'run-time' the statement is passed by.

```
1E27    DATA        CALL    2530,SYNTAX-Z       Jump forward unless checking
                    JR      NZ,1E37,DATA-2      syntax.
```

A loop is now entered to deal with each expression in the DATA statement.

```
1E2C    DATA-1      CALL    24FB,SCANNING       Scan the next expression.
                    CP      +2C                 Check for the correct
                                                separator - a ',';
                    CALL    NZ,1BEE,CHECK-END   but move on to the next
                                                statement if not matched.
                    RST     0020,NEXT-CHAR      Whilst there are still
                    JR      1E2C,DATA-1         expressions to be checked go
                                                around the loop.
```

The DATA statement has to be passed-by in 'run-time'.

```
1E37    DATA-2      LD      A,+E4               It is a 'DATA' statement that
                                                is to be passed-by.
```

THE 'PASS-BY' SUBROUTINE

On entry the A register will hold either the token 'DATA' or the token 'DEF FN' depending on the type of statement that is being 'passed-by'.

```
1E39    PASS-BY     LD      B,A                 Make the BC register pair hold
                                                a very high number.
                    CPDR                        Look back along the statement
                                                for the token.
                    LD      DE,+0200            Now look along the line
                    JP      198B,EACH-STMT      for the statement after. (The
                                                'D-1'th statement from the
                                                current position.
```

THE 'RESTORE' COMMAND ROUTINE

The operand for a RESTORE command is taken as a line number, zero being used if no operand is given.
The REST-RUN entry point is used by the RUN command routine.

```
1E42    RESTORE     CALL    1E99,FIND-INT2      Compress the operand into the
                                                BC register pair.
1E45    REST-RUN    LD      H,B                 Transfer the result to the
                    LD      L,C                 HL register pair.
                    CALL    196E,LINE-ADDR      Now find the address of that
                                                line or the 'first line after'.
                    DEC     HL                  Make DATADD point to the
                    LD      (DATADD),HL         location before.
                    RET                         Return once it is done.
```

THE 'RANDOMIZE' COMMAND ROUTINE

Once again the operand is compressed into the BC register pair and transferred to the required system variable. However if the operand is zero the value in FRAMES1 and FRAMES2 is used instead.

```
1E4F    RANDOMIZE   CALL    1E99,FIND-INT2      Fetch the operand.
                    LD      A,B                 Jump forward unless the
                    OR      C                   value of the operand is
                    JR      NZ,1E5A,RAND-1      zero.
                    LD      BC,(FRAMES1)        Fetch the two low order bytes
                                                of FRAMES instead.
1E5A    RAND-1      LD      (SEED),BC           Now enter the result into the
                    RET                         system variable SEED before
                                                returning.
```

THE 'CONTINUE' COMMAND ROUTINE

The required line number and statement number within that line are made the object of a jump.

```
1E5F    CONTINUE    LD      HL,(OLDPPC)     The line number.
                    LD      D,(OSPPC)       The statement number.
                    JR      1E73,GO-TO-2    Jump forward.
```

THE 'GO TO' COMMAND ROUTINE

The operand of a GO TO ought to be a line number in the range '1' to '9999' but the actual test is against an upper value of '61439'.

```
1E67    GO-TO       CALL    1E99,FIND-INT2  Fetch the operand and transfer
                    LD      H,B             it to the HL register pair.
                    LD      L,C
                    LD      D,+00           Set the statement number to
                                            zero.
                    LD      A,H             Give the error message
                    CP      +F0             - Integer out of range -
                    JR      NC,1E9F,REPORT-B with lines over '614139'
```

The entry point GO-TO-2 is used to determine the line number of the next line to be handled in several instances.

```
1E73    GO-TO-2     LD      (NEWPPC),HL     Enter the line number and
                    LD      (NSPPC),D       then the statement number.
                    RET     Return; - to STMT-RET.
```

THE 'OUT' COMMAND ROUTINE

The two parameters for the OUT instruction are fetched from the calculator stack and used as directed.

```
1E7A    OUT         CALL    1E85,TWO-PARAM  The operands are fetched.
                    OUT     (C),A           The actual OUT instruction.
                    RET     Return; - to STMT-RET.
```

THE 'POKE' COMMAND ROUTINE

In a similar manner the POKE operation is performed.

```
1E80    POKE        CALL    1E85,TWO-PARAM  The operands are fetched.
                    LD      (BC),A          The actual POKE operation.
                    RET     Return; - to STMT-RET.
```

THE 'TWO-PARAM' SUBROUTINE

The topmost parameter on the calculator stack must be compressible into a single register. It is two's complemented if it is negative. The second parameter must be compressible into a register pair.

```
1E85    TWO-PARAM   CALL    2DD5,FP-TO-A    The parameter is fetched.
                    JR      C,1E9F,REPORT-B Give an error if it is too high
                                            a number.
                    JR      Z,1E8E,TWO-P-1  Jump forward with positive
                    NEG                     numbers but two's complement
                                            negative numbers.
1E8E    TWO-P-1     PUSH    AF              Save the first parameter
                    CALL    1E99,FIND-INT2  whilst the second is fetched.
                    POP     AF              The first parameter is
                    RET                     restored before returning.
```

THE 'FIND INTEGERS' SUBROUTINE

The 'last value' on the calculator stack is fetched and compressed into a single register or a register pair by entering at FIND-INT1 AND FIND-INT2 respectively.

```
1E94    FIND-INT1   CALL    2DD5,FP-TO-A    Fetch the 'last value'.
                    JR      1E9C,FIND-I-1   Jump forward.
1E99    FIND-INT2   CALL    2DA2,FP-TO-BC   Fetch the 'last value'.
1E9C    FIND-I-1    JR      C,1E9F,REPORT-B In both cases overflow is
```

```
                                                  indicated by a set carry flag.
                    RET         Z                 Return with all positive
                                                  numbers that are in range.
Report B - Integer out of range
1E9F    REPORT-B    RST         0008,ERROR-1      Call the error handling
                    DEFB        +0A               routine.
```

THE 'RUN' COMMAND ROUTINE

The parameter of the RUN command is passed to NEWPPC by calling the GO TO command routine. The operations of 'RESTORE 0' and 'CLEAR 0' are then performed before a return is made.

```
1EA1    RUN         CALL        1E67,GO-TO        Set NEWPPC as required.
                    LD          BC,+0000          Now perform a 'RESTORE 0'.
                    CALL        1E45,REST-RUN
                    JR          1EAF,CLEAR-1      Exit via the CLEAR command routine.
```

THE 'CLEAR' COMMAND ROUTINE

This routine allows for the variables area to be cleared, the display area cleared and RAMTOP moved. In consequence of the last operation the machine stack is rebuilt thereby having the effect of also clearing the GO SUB stack.

```
1EAC    CLEAR       CALL        1E99,FIND-INT2    Fetch the operand - using
                                                  zero by default.
1EAF    CLEAR-RUN   LD          A,B               Jump forward if the operand is
                    OR          C                 other than zero. When called
                    JR          NZ,1EB7,CLEAR-1   from RUN there is no jump.
                    LD          BC,(RAMTOP)       If zero use the existing value in
                                                  RAMTOP.
1EB7    CLEAR-1     PUSH        BC                Save the value.
                    LD          DE,(VARS)         Next reclaim all the bytes
                    LD          HL,(E-LINE)       of the present variables
                    DEC         HL                area.
                    CALL        19E5,RECLAIM-1
                    CALL        0D6B,CLS          Clear the display area.
```

The value in the BC register pair which will be used as RAMTOP is tested to ensure it is neither too low nor too high.

```
                    LD          HL,(STKEND)       The current value of STKEND.
                    LD          DE,+0032          is increased by '50' before
                    ADD         HL,DE             being tested. This forms the
                    POP         DE                lower limit.
                    SBC         HL,DE
                    JR          NC,1EDA,REPORT-M  RAMTOP will be too low.
                    LD          HL,(P-RAMT)       For the upper test the value
                    AND         A                 for RAMTOP is tested against
                    SBC         HL,DE             P-RAMT.
                    JR          NC,1EDC,CLEAR-2   Jump forward if acceptable.
```

Report M - RAMTOP no good

```
1EDA    REPORT-M    RST         0008,ERROR-1      Call the error handling
                    DEFB        +15               routine.
```

Continue with the CLEAR operation.

```
1EDC    CLEAR-2     EX          DE,HL             Now the value can actually be
                    LD          (RAMTOP),HL       passed to RAMTOP.
                    POP         DE                Fetch the address - STMT-RET.
                    POP         BC                Fetch the 'error address'.
                    LD          (HL),+3E          Enter a GO SUB stack end
                                                  marker.
                    DEC         HL                Leave one location.
                    LD          SP,HL             Make the stack pointer point
```

```
                                                to an empty GO SUB stack.
                PUSH    BC                      Next pass the 'error address'
                LD      (ERR-SP),SP             to the stack and save its
                                                address in ERR-SP.
                EX      DE,HL                   An indirect return is now
                JP      (HL)                    made to STMT-RET.
```

Note: When the routine is called from RUN the values of NEWPPC & NSPPC will have been affected and no statements coming after RUN can ever be found before the jump is taken.

THE 'GO SUB' COMMAND ROUTINE

The present value of PPC and the incremented value of SUBPPC are stored on the GO SUB stack.

```
1EED    GO-SUB  POP     DE                      Save the address - STMT-RET.
                LD      H,(SUBPPC)              Fetch the statement number
                INC     H                       and increment it.
                EX      (SP),HL                 Exchange the 'error address'
                                                with the statement number.
                INC     SP                      Reclaim the use of a location.
                LD      BC,(PPC)                Next save the present line
                PUSH    BC                      number.
                PUSH    HL                      Return the 'error address'
                LD      (ERR-SP),SP             to the machine stack and
                                                reset ERR-SP to point to it.
                PUSH    DE                      Return the address -
                                                STMT-RET.
                CALL    1E67,GO-TO-1            Now set NEWPPC & NSPPC to
                                                the required values.
                LD      BC,+0014                But before making the jump
                                                make a test for room.
```

THE 'TEST-ROOM' SUBROUTINE

A series of tests is performed to ensure that there is sufficient free memory available for the task being undertaken.

```
1F05    TEST-ROOM LD    HL,(STKEND)             Increase the value taken from
                ADD     HL,BC                   STKEND by the value carried
                                                into the routine by the BC
                                                register pair.
                JR      C,1F15,REPORT-4         Jump forward if the result is
                                                over +FFFF.
                EX      DE,HL                   Try it again allowing for a
                LD      HL,+0050                further eighty bytes.
                ADD     HL,DE
                JR      C,1F15,REPORT-4
                SBC     HL,SP                   Finally test the value against the
                                                address of the machine stack.
                RET     C                       Return if satisfactory.
Report 4 - Out of memory
1F15    REPORT-4  LD    L,+03                   This is a 'run-time' error and the
                JP      0055,ERROR-3            error marker is not to be used.
```

THE 'FREE MEMORY' SUBROUTINE

There is no BASIC command 'FRE' in the SPECTRUM but there is a subroutine for performing such a task.
An estimate of the amount of free space can be found at any time by using:
'PRINT 65536-USR 7962'

```
1F1A    FREE-MEM  LD    BC,+0000                Do not allow any overhead.
                CALL    1F05,TEST-ROOM          Make the test and pass the
```

```
                LD      B,H             result to the BC register
                LD      C,L             before returning.
                RET
```

THE 'RETURN' COMMAND ROUTINE

The line number and the statement number that are to be made the object of a 'return' are fetched from the GO SUB stack.

```
1F23    RETURN  POP     BC              Fetch the address - STMT-RET.
                POP     HL              Fetch the 'error address'.
                POP     DE              Fetch the last entry on the
                                        GO SUB stack.
                LD      A,D             The entry is tested to see if
                CP      +3E             it is the GO SUB stack end
                JR      Z,1F36,REPORT-7 marker; jump if it is.
                DEC     SP              The full entry uses three
                                        locations only.
                EX      (SP),HL         Exchange the statement number
                                        with the 'error address'.
                EX      DE,HL           Move the statement number.
                LD      (ERR-SP),SP     Reset the error pointer.
                PUSH    BC              Replace the address -
                                        STMT-RET.
                JP      1E73,GO-TO-2    Jump back to change NEWPPC
                                        & NSPPC.
```

Report 7 - RETURN without GOSUB

```
1F36    REPORT-7 PUSH   DE              Replace the end marker and
                PUSH    HL              the 'error address'.
                RST     0008,ERROR-1    Call the error handling
                DEFB    +06             routine.
```

THE 'PAUSE' COMMAND ROUTINE

The period of the PAUSE is determined by counting the number of maskable interrupts as they occur every 1/50 th. of a second.
A PAUSE is finished either after the appropriate number of interrupts or by the system Variable FLAGS indicating that a key has been pressed.

```
1F3A    PAUSE   CALL    1E99,FIND-INT2  Fetch the operand.
1F3D    PAUSE-1 HALT                    Wait for a maskable interrupt.
                DEC     BC              Decrease the counter.
                LD      A,B             If the counter is thereby
                OR      C               reduced to zero the PAUSE
                JR      Z,1F4F,PAUSE-END has come to an end.
                LD      A,B             If the operand was zero BC
                AND     C               will now hold +FFFF and this
                INC     A               value will be returned to
                JR      NZ,1F49,PAUSE-2 zero. Jump will all other
                INC     BC              operand values.
1F49    PAUSE-2 BIT     5,(FLAGS)       Jump back unless a key has
                JR      Z,1F3D,PAUSE-1  been pressed.
```

The period of the PAUSE has now finished.

```
1F4F    PAUSE-END RES   5,(FLAGS)       Signal 'no key pressed'.
                RET                     Now return; - to STMT-RET.
```

THE 'BREAK-KEY' SUBROUTINE

This subroutine is called in several instances to read the BREAK key. The carry flag is returned reset only if the SHIFT and the BREAK keys are both being pressed.

```
1F54    BREAK-KEY LD    A,+7F           Form the port address
                IN      A,(+FE)         +7FFE and read in a byte.
                RRA                     Examine only bit 0 by shifting
                                        it into the carry position.
```

```
                RET     C               Return if the BREAK key is
                                        not being pressed.
                LD      A,+FE           Form the port address
                IN      A,(+FE)         +FEFE and read in a byte.
                RRA                     Again examine bit 0.
                RET                     Return with carry reset if
                                        both keys are being pressed.
```

THE 'DEF FN' COMMAND ROUTINE

During syntax checking a DEF FN statement is checked to ensure that it has the correct form. Space is also made available for the result of evaluating the function.
But in 'run-time' a DEF FN statement is passed-by.

```
1F60    DEF-FN      CALL    2530,SYNTAX-Z   Jump forward if checking
                    JR      Z,1F6A,DEF-FN-1 syntax.
                    LD      A,+CE           Otherwise bass-by the
                    JP      1E39,PASS-BY    'DEF FN' statement.
```

First consider the variable of the function.

```
1F6A    DEF-FN-1    SET     6,(FLAGS)       Signal 'a numeric variable'.
                    CALL    2C8D,ALPHA      Check that the present
                                            code is a letter.
                    JR      NC,1F89,DEF-FN-4 Jump forward if not.
                    RST     0020,NEXT-CHAR  Fetch the next character.
                    CP      +24             Jump forward unless it is
                    JR      NZ,1F7D,DEF-FN-2 a '$'.
                    RES     6,(FLAGS)       Change bit 6 as it is a
                                            string variable.
                    RST     0020,NEXT-CHAR  Fetch the next character.
1F7D    DEF-FN-2    CP      +28             A '(' must follow the
                    JR      NZ,1FBD,DEF-FN-7 variable's name.
                    RST     0020,NEXT-CHAR  Fetch the next character.
                    CP      +29             Jump forward if it is a
                    JR      Z,1FA6,DEF-FN-6 ')' as there are no
                                            parameters of the function.
```

A loop is now entered to deal with each parameter in turn.

```
1F86    DEF-FN-3    CALL    2C8D,ALPHA      The present code must be
1F89    DEF-FN-4    JP      NC,1C8A,REPORT-C a letter.
                    EX      DE,HL           Save the pointer in DE.
                    RST     0020,NEXT-CHAR  Fetch the next character.
                    CP      +24             Jump forward unless it is
                    JR      NZ,1F94,DEF-FN-5 a '$'.
                    EX      DE,HL           Otherwise save the new pointer
                                            in DE instead.
                    RST     0020,NEXT-CHAR  Fetch the next character.
1F94    DEF-FN-5    EX      DE,HL           Move the pointer to the last
                                            character of the name to the HL
                                            register pair.
                    LD      BC,+0006        Now make six locations after
                    CALL    1655,MAKE-ROOM  that last character and
                    INC     HL              enter a 'number marker' into
                    INC     HL              the first of the new
                    LD      (HL),+0E        locations.
                    CP      +2C             If the present character is
                    JR      NZ,1FA6,DEF-FN-6 a ',' then jump back as
                    RST     0020,NEXT-CHAR  there should be a further
                    JR      1F86,DEF-FN-3   parameter; otherwise jump
                                            out of the loop.
```

Next the definition of the function is considered.

```
1FA6    DEF-FN-6    CP      +29             Check that the ')' does
                    JR      NZ,1FBD,DEF-FN-7 exist.
```

```
                RST     0020,NEXT-CHAR      The next character is fetched.
                CP      +3D                 It must be an '='.
                JR      NZ,1FBD,DEF-FN-7
                RST     0020,NEXT-CHAR      Fetch the next character.
                LD      A,(FLAGS)           Save the nature - numeric or
                PUSH    AF                  string - of the variable.
                CALL    2F4B,SCANNING       Now consider the definition
                                            as an expression.
                POP     AF                  Fetch the nature of the
                XOR     (FLAGS)             variable and check that it
                AND     +40                 is of the same type as found
                                            for the definition.
1FBD  DEF-FN-7  JP      NZ,1C8A,REPORT-C    Give an error report if it
                                            is required.
                CALL    1BEE,CHECK-END      Exit via the CHECK-END
                                            subroutine. (Thereby moving
                                            on to consider the next state-
                                            ment in the line.)
```

THE 'UNSTACK-Z' SUBROUTINE

This subroutine is called in several instances in order to 'return early' from a subroutine when checking syntax. The reason for this is to avoid actually printing characters or passing values to/from the calculator stack.

```
1FC3  UNSTACK-Z CALL    2530,SYNTAX-Z       Is syntax being checked?
                POP     HL                  Fetch the return address but
                RET     Z                   ignore it in 'syntax-time'.
                JP      (HL)                In 'run-time' make a simple
                                            return to the calling routine.
```

THE 'LPRINT & PRINT' COMMAND ROUTINES

The appropriate channel is opened as necessary and the items to be printed are considered in turn.

```
1FC9  LPRINT    LD      A,+03               Prepare to open channel 'P'.
                JR      1FCF,PRINT-1        Jump forward.
1FCD  PRINT     LD      A,+02               Prepare to open channel 'S'.
1FCF  PRINT-1   CALL    2530,SYNTAX-Z       Unless syntax is being
                CALL    NZ,1601,CHAN-OPEN   checked open a channel.
                CALL    0D4D,TEMPS          Set the temporary colour
                                            system variables.
                CALL    1FDF,PRINT-2        Call the print controlling
                                            subroutine.
                CALL    1BEE,CHECK-END      Move on to consider the next
                RET                         statement; via CHECK-END IF
                                            checking syntax.
```

The print controlling subroutine is called by the PRINT, LPRINT and INPUT command routines.

```
1FDF  PRINT-2   RST     0018,GET-CHAR       Get the first character.
                CALL    2045,PR-END-Z       Jump forward if already at the
                JR      Z,1FF2,PRINT-4      end of the item list.
```

Now enter a loop to deal with the 'position controllers' and the print items.

```
1FE5  PRINT-3   CALL    204E,PR-POSN-1      Deal with any consecutive
                JR      Z,1FE5,PRINT-3      position controllers.
                CALL    1FFC,PR-ITEM-1      Deal with a single print item.
                CALL    204E,PR-POSN-1      Check for further position
                JR      Z,1FE5,PRINT-3      controllers and print items
                                            until there are none left.
1FF2  PRINT-4   CP      +29                 Return now if the present
                RET     Z                   character is a ')'; otherwise
                                            consider performing a 'carriage
                                            return'.
```

THE 'PRINT A CARRIAGE RETURN' SUBROUTINE

```
1FF5    PRINT-CR    CALL    1FC3,UNSTACK-Z      Return if changing syntax.
                    LD      A,+0D               Print a carriage return
                    RST     0010,PRINT-A-1      character and then return.
                    RET
```

THE 'PRINT ITEMS' SUBROUTINE

This subroutine is called from the PRINT, LPRINT and INPUT command routines.
The various types of print item are identified and printed.

```
1FFC    PR-ITEM-1   RST     0018,GET-CHAR       The first character is fetched.
                    CP      +AC                 Jump forward unless it is
                    JR      NZ,200E,PR-ITEM-2   an 'AT'.
Now deal with an 'AT'.
                    CALL    1C79,NEXT-2NUM      The two parameters are trans-
                                                ferred to the calculator stack.
                    CALL    1FC3,UNSTACK-Z      Return now if checking syntax.
                    CALL    2307,STK-TO-BC      The parameters are compressed
                                                into the BC register pair.
                    LD      A,+16               The A register is loaded with
                    JR      201E,PR-AT-TAB      the AT control character before
                                                the jump is taken.
Next look for a 'TAB'.
200E    PR-ITEM-2   CP      +AD                 Jump forward unless it is
                    JR      NZ,2024,PR-ITEM-3   a 'TAB'.
Now deal with a 'TAB'.
                    RST     0020,NEXT-CHAR      Get the next character.
                    CALL    1C82,EXPT-1NUM      Transfer one parameter to the
                                                calculator stack.
                    CALL    1FC3,UNSTACK-Z      Return now if checking syntax.
                    CALL    1E99,FIND-INT2      The value is compressed into the
                                                BC register pair.
                    LD      A,+17               The A register is loaded with the
                                                TAB control character.
The 'AT' and the 'TAB' print items are printed by making three calls to PRINT-OUT.
201E    PR-AT-TAB   RST     0010,PRINT-A-1      Print the control character.
                    LD      A,C                 Follow it with the first
                    RST     0010,PRINT-A-1      value.
                    LD      A,B                 Finally print the second
                    RST     0010,PRINT-A-1      value; then return.
                    RET
Next consider embedded colour items.
2024    PR-ITEM-3   CALL    21F2,CO-TEMP-3      Return with carry reset if a
                                                colour items was found.
                    RET     NC                  Continue if none were found.
                    CALL    2070,STR-ALTER      Next consider if the stream is
                                                to be changed.
                    RET     NC                  Continue unless it was altered.
The print item must now be an expression, either numeric or string.
                    CALL    24FB,SCANNING       Evaluate the expression but
                    CALL    1FC3,UNSTACK-Z      return now if checking syntax.
                    BIT     6,(FLAGS)           Test for the nature of the
                                                expression.
                    CALL    Z,2BF1,STK-FETCH    If it is string then fetch the nec-
                                                essary parameters; but if it is
                    JP      NZ,2DE3,PRINT-FP    numeric then exit via PRINT-FP.
```

A loop is now set up to deal with each character in turn of the string.

```
203C    PR-STRING   LD      A,B             Return now if there are
                    OR      C               no characters remaining
                    DEC     BC              in the string; otherwise
                    RET     Z               decease the counter.
                    LD      A,(DE)          Fetch the code and increment
                    INC     DE              the pointer.
                    RST     0010,PRINT-A-1  The code is printed and a jump
                    JR      203C,PR-STRING  taken to consider any further
                                            characters.
```

THE 'END OF PRINTING' SUBROUTINE

The zero flag will be set if no further printing is to be done.

```
2045    PR-END-Z    CP      +29             Return now if the character
                    RET     Z               is a ')'.
2048    PR-ST-END   CP      +0D             Return now if the character is
                    RET     Z               a 'carriage return'.
                    CP      +3A             Make a final test against ':'
                    RET                     before returning.
```

THE 'PRINT POSITION' SUBROUTINE

The various position controlling characters are considered by this subroutine.

```
204E    PR-POSN-1   RST     0018,GET-CHAR   Get the present character.
                    CP      +3B             Jump forward if it is
                    JR      Z,2067,PR-POSN-3 a ';'.
                    CP      +2C             Also jump forward with a
                    JR      NZ,2061,PR-POSN-2 character other than a ',';
                    CALL    2530,SYNTAX-Z   but do not actually print the
                    JR      Z,2067,PR-POSN-3 character if checking syntax.
                    LD      A,+06           Load the A register with
                    RST     0010,PRINT-A-1  the 'comma' control code and
                    JR      2067,PR-POSN-3  print it; then jump forward.
2061    PR-POSN-2   CP      +27             Is it a '"?
                    RET     NZ              Return now if not any of the
                                            position controllers.
                    CALL    1FF5,PR-CR      Print 'carriage return' unless
                                            checking syntax.
2067    PR-POSN-3   RST     0020,NEXT-CHAR  Fetch the next character.
                    CALL    2045,PR-END-Z   If not at the end of a print
                    JR      NZ,206E,PR-POSN-4 statement then jump forward;
                    POP     BC              otherwise return to the
206E    PR-POSN-4   CP      A               calling routine.
                    RET                     The zero flag will be reset if the
                                            end of the print statement has
                                            not been reached.
```

THE 'ALTER STREAM' SUBROUTINE

This subroutine is called whenever there is the need to consider whether the user wishes to use a different stream.

```
2070    STR-ALTER   CP      +23             Unless the present character
                    SCF                     is a '#' return with the
                    RET     NZ              carry flag set.
                    RST     0020,NEXT-CHAR  Advance CH-ADD.
                    CALL    1C82,EXPT-1NUM  Pass the parameter to the
                                            calculator stack.
                    AND     A               Clear the carry flag.
                    CALL    1FC3,UNSTACK-Z  Return now if checking syntax.
                    CALL    1E94,FIND-INT1  The value is passed to the A
                                            register.
                    CP      +10             Give report O if the value is
```

```
                JP      NC,160E,REPORT-O    over +FF.
                CALL    1601,CHAN-OPEN      Use the channel for the
                                            stream in question.
                AND     A                   Clear the carry flag and
                RET                         return.
```

THE 'INPUT' COMMAND ROUTINE

This routine allows for values entered from the keyboard to be assigned to variables. It is also possible to have print items embedded in the INPUT statement and these items are printed in the lower part of the display.

```
2089  INPUT     CALL    2530,SYNTAX-Z       Jump forward if syntax is
                JR      Z,2096,INPUT-1      being checked.
                LD      A,+01               Open channel 'K'.
                CALL    1601,CHAN-OPEN
                CALL    0D6E,CLS-LOWER      The lower part of the display
                                            is cleared.
2096  INPUT-1   LD      (TV-FLAG),+01       Signal that the lower screen is being
                                            handled. Reset all other bits.
                CALL    20C1,IN-ITEM-1      Call the subroutine to deal with
                                            the INPUT items.
                CALL    1BEE,CHECK-END      Move on to the next statement
                                            if checking syntax.
                LD      BC,(S-POSN)         Fetch the current print position.
                LD      A,(DF-SZ)           Jump forward if the current
                CP      B                   position is above the lower
                JR      C,20AD,INPUT-2      screen.
                LD      C,+21               Otherwise set the print position
                LD      B,A                 to the top of the lower screen.
20AD  INPUT-2   LD      (S-POSN),BC         Reset S-POSN.
                LD      A,+19               Now set the scroll counter.
                SUB     B
                LD      (SCR-CT),A
                RES     0,(TV-FLAG)         Signal 'main screen'.
                CALL    0DD9,CL-SET         Set the system variables
                JP      0D6E,CLS-LOWER      and exit via CLS-LOWER.
```

The INPUT items and embedded PRINT items are dealt with in turn by the following loop.

```
20C1  IN-ITEM-1 CALL    204E,PR-POSN-1      Consider first any position
                JR      Z,20C1,IN-ITEM-1    control characters.
                CP      +28                 Jump forward if the present
                JR      NZ,20D8,IN-ITEM-2   character is not a '('.
                RST     0020,NEXT-CHAR      Fetch the next character.
                CALL    1FDF,PRINT-2        Now call the PRINT command
                                            routine to handle the items
                                            inside the brackets.
                RST     0018,GET-CHAR       Fetch the present character.
                CP      +29                 Give report C unless the
                JP      NZ,1C8A,REPORT-C    character is a ')'.
                RST     0020,NEXT-CHAR      Fetch the next character and
                JP      21B2,IN-NEXT-2      jump forward to see if there are
                                            any further INPUT items.
```

Now consider whether INPUT LINE is being used.

```
20D8  IN-ITEM-2 CP      +CA                 Jump forward if it is not
                JR      NZ,20ED,IN-ITEM-3   'LINE'.
                RST     0020,NEXT-CHAR      Advance CH-ADD.
                CALL    1C1F,CLASS-01       Determine the destination
                                            address for the variable.
                SET     7,(FLAGX)           Signal 'using INPUT LINE'.
                BIT     6,(FLAGS)           Give report C unless using
                JP      NZ,1C8A,REPORT-C    a string variable.
```

```
                    JR      20FA,IN-PROMPT      Jump forward to issue the
                                                prompt message.
Proceed to handle simple INPUT variables.
20ED  IN-ITEM-3     CALL    2C8D,ALPHA          Jump to consider going round
                    JP      NC,21AF-IN-NEXT-1   the loop again if the present
                                                character is not a letter.
                    CALL    1C1F,CLASS-01       Determine the destination
                                                address for the variable.
                    RES     7,(FLAGX)           Signal 'not INPUT LINE'.
The prompt message is now built up in the work space.
20FA  IN-PROMPT     CALL    230,SYNTAX-Z        Jump forward if only checking
                    JP      Z,21B2,IN-NEXT-2    syntax.
                    CALL    16BF,SET-WORK       The work space is set to null.
                    LD      HL,+5C71            This is FLAGX.
                    RES     6,(HL)              Signal 'string result'.
                    SET     5,(HL)              Signal 'INPUT mode'.
                    LD      BC,+0001            Allow the prompt message only
                                                a single location.
                    BIT     7,(HL)              Jump forward if using 'LINE'.
                    JR      NZ,211C,IN-PR-2
                    LD      A,(FLAGS)           Jump forward if awaiting
                    AND     +40                 a numeric entry.
                    JR      NZ,211A,IN-PR-1
                    LD      C,+03               A string entry will need three
                                                locations.
211A  IN-PR-1       OR      (HL)                Bit 6 of FLAGX will become
                    LD      (HL),A              set for a numeric entry.
211C  IN-PR-2       RST     0030,BC-SPACES      The required number of
                                                locations is made available.
                    LD      (HL),+0D            A 'carriage return' goes into
                                                the last location.
                    LD      A,C                 Test bit 6 of the C register
                    RRCA                        and jump forward if only
                    RRCA                        one location was required.
                    JR      NC,2129,IN-PR-3
                    LD      A,+22               A 'double quotes' character
                    LD      (DE),A              goes into the first and
                    DEC     HL                  second locations.
                    LD      (HL),A
2129  IN-PR-3       LD      (K-CUR),HL          The position of the cursor
                                                can now be saved.
In the case of INPUT LINE the EDITOR can be called without further preparation but for other types of INPUT the error stack has to be
changed so as to trap errors.
                    BIT     7,(FLAGX)           Jump forward with INPUT
                    JR      NZ,215E,IN-VAR-3    LINE'
                    LD      HL,(CH-ADD)         Save the current values of
                    PUSH    HL                  CH-ADD & ERR-SP on the
                    LD      HL,(ERR-SP)         machine stack.
                    PUSH    HL
213A  IN-VAR-1      LD      HL,+213A            This will be the 'return
                    PUSH    HL                  point' in case of errors.
                    BIT     4,(FLAGS2)          Only change the error
                    JR      Z,2148,IN-VAR-2     stack pointer if using channel
                    LD      (ERR-SP),SP         'K'.
2148  IN-VAR-2      LD      HL,(WORKSP)         Set HL to the start of the
                    CALL    11A7,REMOVE-FP      INPUT line and remove any
                                                floating-point forms. (There will
                                                not be any except perhaps after
                                                an error.)
                    LD      (ERR-NR),+FF        Signal 'no error yet'.
```

```
                    CALL    0F2C,EDITOR     Now get the INPUT and with
                    RES     7,(FLAGS)       the syntax/run flag indicating
                    CALL    21B9,IN-ASSIGN  syntax, check the INPUT for
                    JR      2161,IN-VAR-4   errors; jump if in order; return
                                            to IN-VAR-1 if not.
215E    IN-VAR-3    CALL    0F2C,EDITOR     Get a 'LINE'.
```

All the system variables have to be reset before the actual assignment of a value can be made.

```
2161    IN-VAR-4    LD      (K-CUR-hi),+00  The cursor address is reset.
                    CALL    21D6,IN-CHAN-K  The jump is taken if using
                    JR      NZ,2174,IN-VAR-5 other than channel 'K'.
                    CALL    111D,ED-COPY    The input-line is copied to
                    LD      BC,(ECHO-E)     the display and the position
                    CALL    0DD9,CL-SET     in ECHO-E made the current
                                            position in the lower screen.
2174    IN-VAR-5    LD      HL,+5C71        This is FLAGX.
                    RES     5,(HL)          Signal 'edit mode'.
                    BIT     7,(HL)          Jump forward if handling an
                    RES     7,(HL)          INPUT LINE.
                    JR      NZ,219B,IN-VAR-6
                    POP     HL              Drop the address IN-VAR-1.
                    POP     HL              Reset the ERR-SP to its
                    LD      (ERR-SP),HL     original address.
                    POP     HL              Save the original CH-ADD
                    LD      (X-PTR),HL      address in X-PTR.
                    SET     7,(FLAGS)       Now with the syntax/run flag
                    CALL    21B9,IN-ASSIGN  indicating 'run' make the
                                            assignment.
                    LD      HL,(X-PTR)      Restore the original address
                    LD      (X-PTR-hi),+00  to CH-ADD and clear X-PTR.
                    LD      (CH-ADD),HL
                    JR      21B2,IN-NEXT-2  Jump forward to see if there
                                            are further INPUT items.
219B    IN-VAR-6    LD      HL,(STKBOT)     The length of the 'LINE' in
                    LD      DE,(WORKSP)     the work space is found.
                    SCF
                    SBC,    HL,DE
                    LD      B,H             DE points to the start and
                    LD      C,L             BC holds the length.
                    CALL    2AB2,STK-ST-$   These parameters are stacked
                    CALL    2AFF,LET        and the actual assignment made.
                    JR      21B2,IN-NEXT-2  Also jump forward to consider
                                            further items.
```

Further items in the INPUT statement are considered.

```
21AF    IN-NEXT-1   CALL    1FFC,PR-ITEM-1  Handle any print items.
21B2    IN-NEXT-2   CALL    204E,PR-POSN-1  Handle any position controllers.
                    JP      Z,20C1,IN-ITEM-1 Go around the loop again if
                                            there are further items;
                    RET                     otherwise return.
```

THE 'IN-ASSIGN' SUBROUTINE

This subroutine is called twice for each INPUT value. Once with the syntax/run flag reset (syntax) and once with it set (run).

```
21B9    IN-ASSIGN   LD      HL,(WORKSP)     Set CH-ADD to point to the
                    LD      (CH-ADD),HL     first location of the work
                    RST     0018,GET-CHAR   space and fetch the character.
                    CP      +E2             Is it a 'STOP'?
                    JR      Z,21D0,IN-STOP  Jump if it is.
                    LD      A,(FLAGX)       Otherwise make the assignment
                    CALL    1C59,VAL-FET-2  of the 'value' to the variable.
```

```
                    RST     0018,GET-CHAR       Get the present character
                    CP      +0D                 and check it is a 'carriage
                    RET     Z                   return'. Return if it is.
Report C - Nonsense in BASIC
21CE    REPORT-C    RST     0008,ERROR-1        Call the error handling
                    DEFB    +0B                 routine.
Come here if the INPUT line starts with 'STOP'.
21D0    IN-STOP     CALL    2530,SYNTAX-Z       But do not give the error
                    RET     Z                   report on the syntax-pass.
Report H - STOP in INPUT
21D4    REPORT-H    RST     0008,ERROR-1        Call the error handling
                    DEFB    +10                 routine.
```

THE 'IN-CHAN-K' SUBROUTINE

This subroutine returns with the zero flag reset only if channel 'K' is being used.

```
21D6    IN-CHAN-K   LD      HL,(CURCHL)         The base address of the
                    INC     HL                  channel information for the
                    INC     HL                  current channel is fetched
                    INC     HL                  and the channel code compared
                    INC     HL                  to the character 'K'.
                    LD      A,(HL)
                    CP      +4B
                    RET                         Return afterwards.
```

THE 'COLOUR ITEM' ROUTINES

This set of routines can be readily divided into two parts:
i. The embedded colour item' handler.
ii. The 'colour system variable' handler.
i. Embedded colour items are handled by calling the PRINT-OUT subroutine as required.
A loop is entered to handle each item in turn. The entry point is at CO-TEMP-2.

```
21E1    CO-TEMP-1   RST     0020,NEXT-CHAR      Consider the next character
                                                in the BASIC statement.
21E2    CO-TEMP-2   CALL    21F2,CO-TEMP-3      Jump forward to see if the
                                                present code represents an
                                                embedded 'temporary' colour
                    RET     C                   item. Return carry set if not a
                                                colour item.
                    RST     0018,GET-CHAR       Fetch the present character.
                    CP      +2C                 Jump back if it is either a
                    JR      Z,21E1,CO-TEMP-1    ',' or a ';'; otherwise
                    CP      +3B                 there has been an error.
                    JR      Z,21E1,CO-TEMP-1
                    JP      1C8A,REPORT-C       Exit via 'report C'.
21F2    CO-TEMP-3   CP      +D9                 Return with the carry flag
                    RET     C                   Set if the code is not in the
                    CP      +DF                 range +D9 to +DE (INK to
                                                OVER).
                    CCF
                    RET     C
                    PUSH    AF                  The colour item code is
                    RST     0020,NEXT-CHAR      preserved whilst CH-ADD is
                    POP     AF                  advanced to address the
                                                parameter that follows it.
The colour item code and the parameter are now 'printed' by calling PRINT-OUT on two occasions.
21FC    CO-TEMP-4   SUB     +C9                 The token range (+D9 to +DE)
```

```
                                                  is reduced to the control
                                                  character range (+10 to +15).
                PUSH    AF                        The control character code is
                CALL    1C82,EXPT-1NUM            preserved whilst the parameter
                POP     AF                        is moved to the calculator stack.
                AND     A                         A return is made at this point
                CALL    1FC3,UNSTACK-Z            if syntax is being checked.
                PUSH    AF                        The control character code is
                CALL    1E94,FIND-INT1            preserved whilst the parameter
                LD      D,A                       is moved to the D register.
                POP     AF
                RST     0010,PRINT-A-1            The control character is sent
                                                  out.
                LD      A,D                       Then the parameter is fetched
                RST     0010,PRINT-A-1            and sent out before
                RET                               returning.
```

ii. The colour system variables - ATTR-T, MASK-T & P-FLAG - are altered as required. This subroutine is called by PRINT-OUT. On entry the control character code is in the A register and the parameter is in the D register.
Note that all changes are to the 'temporary' system variables.

```
2211    CO-TEMP-5   SUB     +11                   Reduce the range and jump
                    ADC     A,+00                 forward with INK & PAPER.
                    JR      Z,2234,CO-TEMP-7
                    SUB     +02                   Reduce the range once again
                    ADC     A,+00                 and jump forward with FLASH
                    JR      Z,2273,CO-TEMP-C      & BRIGHT.
```

The colour control code will now be +01 for INVERSE and +02 for OVER and the system variable P-FLAG is altered accordingly.

```
                    CP      +01                   Prepare to jump with OVER.
                    LD      A,D                   Fetch the parameter.
                    LD      B,+01                 Prepare the mask for OVER.
                    JR      NZ,2228,CO-TEMP-6     Now jump.
                    RLCA                          Bit 2 of the A register is to be
                    RLCA                          reset for INVERSE 0 and set for
                    LD      B,+04                 INVERSE 1; the mask is to have
                                                  bit 2 set.
2228    CO-TEMP-6   LD      C,A                   Save the A register whilst the
                                                  range is tested.
                    LD      A,D                   The correct range for
                    CP      +02                   INVERSE and OVER is only
                    JR      NC,2244,REPORT-K      '0-1'.
                    LD      A,C                   Fetch the A register.
                    LD      HL,+5C91              It is P-FLAG that is to be
                                                  changed.
                    JR      226C,CO-CHANGE        Exit via CO-CHANGE and alter
                                                  P-FLAG using 'B' as a mask.
                                                  i.e. Bit 0 for OVER & bit 2
                                                  for INVERSE'
```

PAPER & INK are dealt with by the following routine. On entry the carry flag is set for INK.

```
2234    CO-TEMP-7   LD      A,D                   Fetch the parameter.
                    LD      B,+07                 Prepare the mask for INK.
                    JR      C,223E,CO-TEMP-8      Jump forward with INK.
                    RLCA                          Multiply the parameter for
                    RLCA                          PAPER by eight.
                    RLCA
                    LD      B,+38                 Prepare the mask for PAPER.
223E    CO-TEMP-8   LD      C,A                   Save the parameter in the C
                                                  register whilst the range of the
                                                  parameter is tested.
```

```
                        LD      A,D             Fetch the original value.
                        CP      +0A             Only allow PAPER/INK a
                        JR      C,2246,CO-TEMP-9 range of '0' to '9'.
Report K - Invalid colour
2244    REPORT-K        RST     0008,ERROR-1    Call the error handling
                        DEFB    +13             routine.
Continue to handle PAPER & INK;
2246    CO-TEMP-9       LD      HL,+5C8F        Prepare to alter ATTR-T,
                                                MASK-T & P-FLAG.
                        CP      +08             Jump forward with PAPER/INK
                        JR      C,2258,CO-TEMP-B '0' to 5'7'.
                        LD      A,(HL)          Fetch the current value of
                        JR      Z,2257,CO-TEMP-A ATTR-T and use it unchanged,
                                                by jumping forward, with
                                                PAPER/INK '8'.
                        OR      B               But for PAPER/INK '9' the
                        CPL                     PAPER and INK colours
                        AND     +24             have to be black and white.
                        JR      Z,2257,CO-TEMP-A Jump for black INK/PAPER;
                        LD      A,B             but continue for white INK/
                                                PAPER.
2257    CO-TEMP-A       LD      C,A             Move the value to the C register.
The mask (B) and the value (C) are now used to change ATTR-T.
2258    CO-TEMP-B       LD      A,C             Move the value.
                        CALL    226C,CO-CHANGE  Now change ATTR-T as needed.
Next MASK-T is considered.
                        LD      A,+07           The bits of MASK-T are set
                        CP      D               only when using PAPER/INK
                        SBC     A,A             '8' or '9'.
                        CALL    226C,CO-CHANGE  Now change MASK-T as needed.
Next P-FLAG is considered.
                        RLCA                    The appropriate mask is
                        RLCA                    built up in the B register
                        AND     +50             is order to change bits 4 &
                        LD      B,A             6 as necessary.
                        LD      A,+08           The bits of P-FLAG are set
                        CP      D               only when using PAPER/INK
                        SBC     A,A             '9'.
                                                Continue into CO-CHANGE to
                                                manipulate P-FLAG.
```

THE 'CO-CHANGE' SUBROUTINE

This subroutine is used to 'impress' upon a system variable the 'nature' of the bits in the A register, The B register holds a mask that shows which bits are to be 'copied over' from A to (HL).

```
226C    CO-CHANGE       XOR     (HL)            The bits, specified by the
                        AND     B               mask in the B register, are
                        XOR     (HL)            changed in the value and the
                        LD      (HL),A          result goes to form the
                                                system variable.
                        INC     HL              Move on to address the next
                                                system variable.
                        LD      A,B             Return with the mask in the
                        RET                     A register.
```

FLASH & BRIGHT are handled by the following routine.

```
2273    CO-TEMP-C   SBC     A,A             The zero flag will be set for
                                            BRIGHT.
                    LD      A,D             The parameter is fetched and
                    RRCA                    rotated.
                    LD      B,+80           Prepare the mask for FLASH.
                    JR      NZ,227D,CO-TEMP-D  Jump forward with FLASH.
                    RRCA                    Rotate an extra time and
                    LD      B,+40           prepare the mask for BRIGHT.
227D    CO-TEMP-D   LD      C,A             Save the value in the C register.
                    LD      A,D             Fetch the parameter and test
                    CP      +08             its range; only '0', '1'
                    JR      Z,2287,CO-TEMP-E  & '8' are allowable.
                    CP      +02
                    JR      NC,2244,REPORT-K
The system variable ATTR-T can now be altered.
2287    CO-TEMP-E   LD      A,C             Fetch the value.
                    LD      HL,+5C8F        This is ATTR-T.
                    CALL    226C,CO-CHANGE  Now change the system variable.
The value in MASK-T is now considered.
                    LD      A,C             The value is fetched anew.
                    RRCA                    The set bit of FLASH/BRIGHT
                    RRCA                    '8' (bit 3) is moved to
                    RRCA                    bit 7 (for FLASH) or bit 6
                                            (for BRIGHT).
                    JR      226C,CO-CHANGE  Exit via CO-CHANGE.
```

THE 'BORDER' COMMAND ROUTINE

The parameter of the BORDER command is used with an OUT command to actually alter the colour of the border. The parameter is then saved in the system variable BORDCR.

```
2294    BORDER      CALL    1E94,FIND-INT1  The parameter is fetched
                    CP      +08             and its range is tested.
                    JR      NC,2244,REPORT-K
                    OUT     (+FE),A         The OUT instruction is then
                                            used to set the border colour.
                    RLCA                    The parameter is then
                    RLCA                    multiplied by eight.
                    RLCA
                    BIT     5,A             If the border colour is a 'light'
                    JR      NZ,22A6,BORDER-1  colour then the INK colour in
                                            the editing area is to be black -
                                            make the jump.
                    XOR     +07             Change the INK colour.
22A6    BORDER-1    LD      (BORDCR),A      Set the system variable as
                    RET                     required and return.
```

THE 'PIXEL ADDRESS' SUBROUTINE

This subroutine is called by the POINT subroutine and by the PLOT command routine. Is is entered with the co-ordinates of a pixel in the BC register pair and returns with HL holding the address of the display file byte which contains that pixel and A pointing to the position of the pixel within the byte.

```
22AA    PIXEL-ADD   LD      A,+AF           Test that the y co-ordinate (in
                    SUB     B               B) is not greater than 175.
                    JP      C,24F9,REPORT-B
                    LD      B,A             B now contains 175 minus y.
                    AND     A               A holds b7b6b5b4b3b2b1b0,
                    RRA                     the bite of B. And now
                                            0b7b6b5b4b3b2b1.
                    SCF
                    RRA                     Now 10b7b6b5b4b3b2.
```

```
                AND     A
                RRA                     Now 010b7b6b5b4b3.
                XOR     B
                AND     +F8             Finally 010b7b6b2b1b0, so that
                XOR     B               H becomes 64 + 8*INT (B/64) +
                LD      H,A             B (mod 8), the high byte of the
                LD      A,C             pixel address. C contains X.
                RLCA                    A starts as c7c6c5c4c3c2c1c0.
                RLCA
                RLCA                    And is now c2c1c0c7c6c5c4c3.
                XOR     B
                AND     +C7
                XOR     B               Now c2c1b5b4b3c5c4c3.
                RLCA
                RLCA                    Finally b5b4b3c7c6c5c4c3, so
                LD      L,A             that L becomes 32*INT (B(mod
                LD      A,C             64)/8) + INT(x/8), the low byte.
                AND     +07             A holds x(mod 8): so the pixel
                RET                     is bit (A - 7) within the byte.
```

THE 'POINT' SUBROUTINE

This subroutine is called by the POINT function in SCANNING. It is entered with the co-ordinates of a pixel on the calculator stack, and returns a last value of 1 if that pixel is ink colour, and 0 if it is paper colour.

```
22CB    POINT-SUB   CALL    2307,STK-TO-BC  Y co-ordinate to B, x to C.
                    CALL    22AA,PIXEL-ADD  Pixel address to HL.
                    LD      B,A             B will count A+1 loops to get
                    INC     B               the wanted bit of (HL) to
                    LD      A,(HL)          location 0.
22D4    POINT-LP    RLCA                    The shifts.
                    DJNZ    22D4,POINT-LP
                    AND     +01             The bit is 1 for ink, 0 for paper.
                    JP      2D28,STACK-A    It is put on the calculator stack.
```

THE 'PLOT' COMMAND ROUTINE

This routine consists of a main subroutine plus one line to call it and one line to exit from it. The main routine is used twice by CIRCLE and the subroutine is called by DRAW. The routine is entered with the co-ordinates of a pixel on the calculator stack. It finds the address of that pixel and plots it, taking account of the status of INVERSE and OVER held in the P-FLAG.

```
22DC    PLOT        CALL    2307,STK-TO-BC  Y co-ordinate to B, x to C.
                    CALL    22E5,PLOT-SUB   The subroutine is called.
                    JP      0D4D,TEMPS      Exit, setting temporary colours.
22E5    PLOT-SUB    LD      (COORDS),BC     The system variable is set.
                    CALL    22AA,PIXEL-ADD  Pixel address to HL.
                    LD      B,A             B will count A+1 loops to get a
                    INC     B               zero to the correct place in A.
                    LD      A,+FE           The zero is entered.
22F0    PLOT-LOOP   RRCA                    Then lined up with the pixel
                    DJNZ    22F0,PLOT-LOOP  bit position in the byte.
                    LD      B,A             Then copied to B.
                    LD      A,(HL)          The pixel-byte is obtained in A.
                    LD      C,(P-FLAG)      P-FLAG is obtained and first
                    BIT     0,C             tested for OVER.
                    JR      NZ,22FD,PL-TST-IN Jump if OVER 1.
                    AND     B               OVER 0 first makes the pixel
                                            zero.
22FD    PL-TST-IN   BIT     2,C             Test for INVERSE.
                    JR      NZ,2303,PLOT-END INVERSE 1 just leaves the pixel
                                            as it was (OVER 1) or zero
                                            (OVER 0).
                    XOR     B               INVERSE 0 leaves the pixel
```

		CPL		complemented (OVER 1) or
				1 (OVER 0).
2303	PLOT-END	LD	(HL),A	The byte is entered. Its other
				bits are unchanged in every case.
		JP	0BDB,PO-ATTR	Exit, setting attribute byte.

THE 'STK-TO-BC' SUBROUTINE

This subroutine loads two floating point numbers into the BC register pair. It is thus used to pick up parameters in the range +00-+FF. It also obtains in DE the 'diagonal move' values (+/-1,+/-1) which are used in the line drawing subroutine of DRAW.

2307	STK-TO-BC	CALL	2314,STK-TO-A	First number to A.
		LD	B,A	Hence to B.
		PUSH	BC	Save it briefly.
		CALL	2314,STK-TO-A	Second number to A.
		LD	E,C	Its sign indicator to E.
		POP	BC	Restore first number.
		LD	D,C	Its signs indicator to D.
		LD	C,A	Second number to C.
		RET		BC, DE are now as required.

THE 'STK-TO-A' SUBROUTINE

This subroutine loads the A register with the floating point number held at the top of the calculator stack. The number must be in the range 00-FF.

2314	STK-TO-A	CALL	2DD5,FP-TO-A	Modulus of rounded last value to
		JP	C,24F9,REPORT-B	A if possible; else, report error.
		LD	C,+01	One to C for positive last value.
		RET	Z	Return if value was positive.
		LD	C,+FF	Else change C to +FF (i.e. minus
		RET		one). Finished.

THE 'CIRCLE' COMMAND ROUTINE

This routine draws an approximation to the circle with centre co-ordinates X and Y and radius Z. These numbers are rounded to the nearest integer before use. Thus Z must be less than 87.5, even when (X,Y) is in the centre of the screen. The method used is to draw a series of arcs approximated by straight lines. It is illustrated in the BASIC program in the appendix. The notation of that program is followed here.

CIRCLE has four parts:

I. Tests the radius. If its modulus is less than 1, just plot X,Y;
II. Calls CD-PRMS-1 at 2470-24B6, which is used to set the initial parameters for both CIRCLE and DRAW;
III. Sets up the remaining parameters for CIRCLE, including the initial displacement for the first 'arc' (a straight line in fact);
IV. Jumps into DRAW to use the arc-drawing loop at 2420-24FA.

Parts i. to iii. will now be explained in turn.

i. 2320-23AA. The radius, say Z', is obtained from the calculator stack. Its modulus Z is formed and used from now on. If Z is less than 1, it is deleted from the stack and the point X,Y is plotted by a jump to PLOT.

2320	CIRCLE	RST	0017,GET-CHAR	Get the present character.
		CP	+2C	Test for comma.
		JP	NZ,1C8A,REPORT-C	If not so, report the error.
		RST	0020,NEXT-CHAR	Get next character (the radius).
		CALL	1C82,EXPT-1NUM	Radius to calculator stack.
		CALL	1BEE,CHECK-END	Move to consider next statement
				if checking syntax.
		RST	0028,FP-CALC	Use calculator: the stack holds:
		DEFB	+2A,abs	X, Y, Z
		DEFB	+3D,re-stack	Z is re-stacked; its exponent
		DEFB	+38,end-calc	is therefore available.
		LD	A,(HL)	Get exponent of radius.

```
                CP          +81                 Test whether radius less than 1.
                JR          NC,233B,C-R-GRE-1   If not, jump.
                RST         0028,FP-CALC        If less, delete it from the stack.
                DEFB        +02,delete          The stack holds X, Y.
                DEFB        +38,end-calc
                JR          22DC,PLOT           Just plot the point X, Y.
```

ii. 233B-2346 and the call to CD-PRMS1. 2*PI is stored in mem-5 and CD-PRMS1 is called. This subroutine stores in the B register the number of arcs required for the circle, viz. A=4*INT (PI*SQR Z/4)+4, hence 4, 8, 12 ..., up to a maximum of 32. It also stores in mem-0 to mem-4 the quantities 2*PI/A, SIN(PI/A), 0, COS (2*PI/A) and SIN (2*PI/A).

```
233B    C-R-GRE-1   RST         0028,FP-CALC
                    DEFB        +A3,stk-pi/2        X, Y, Z, PI/2.
                    DEFB        +38,end-calc        Now increase exponent to 83
                    LD          (HL),+83            hex, changing PI/2 into 2*PI.
                    RST         0028,FP-CALC        X, Y, Z, 2*PI.
                    DEFB        +C5,st-mem-5        (2*PI is copied to mem-5).
                    DEFB        +02,delete          X, Y, Z
                    DEFB        +38,end-calc
                    CALL        247D,CD-PRMS1       Set the initial parameters.
```

iii. 2347-2381: the remaining parameters and the jump to DRAW. A test is made to see whether the initial 'arc' length is less than 1. If it is, a jump is made simply to plot X, Y. Otherwise, the parameters are set: X+Z and X-Z*SIN (PI/A) are stacked twice as start and end point, and copied to COORDS as well; zero and 2*Z*SIN (PI/A) are stored in mem-1 and mem-2 as initial increments, giving as first 'arc' the vertical straight line joining X+Z, y-Z*SIN (PI/A) and X+Z, Y+Z*SIN (PI/A). The arc-drawing loop of DRAW will ensure that all subsequent points remain on the same circle as these two points, with incremental angle 2*PI/A. But it is clear that these 2 points in fact subtend this angle at the point X+Z*(1-COS (PI/A)), Y not at X, Y. Hence the end points of each arc of the circle are displaced right by an amount 2*(1-COS (PI/A)), which is less than half a pixel, and rounds to one pixel at most.

```
2347    C-ARC-GE1   PUSH        BC                  Save the arc-count in B.
                    RST         0028,FP-CALC        X,Y,Z
                    DEFB        +31,duplicate       X,Y,Z,Z
                    DEFB        +E1,get-mem-1       X,Y,Z,Z,SIN (PI/A)
                    DEFB        +04,multiply        X,Y,Z,Z*SIN (PI/A)
                    DEFB        +38,end-calc        Z*SIN (PI/A) is half the initial
                    LD          A,(HL)              'arc' length; it is tested to see
                    CP          +80                 whether it is less than 0.5.
                    JR          NC,235A,C-ARC-GE1   If not, the jump is made.
                    RST         0028,FP-CALC        Otherwise, Z is deleted from the
                    DEFB        +02,delete          stack, with the half-arc too; the
                    DEFB        +02,delete          machine stack is cleared; and a
                    DEFB        +38,end-calc        jump is made to plot X, Y.
                    POP         BC
                    JP          22DC,PLOT
235A                RST         0028,FP-CALC        X,Y,Z,Z*SIN (PI/A)
                    DEFB        +C2,st-mem-2        (Z*SIN (PI/A) to mem-2 for
                                                    now).
                    DEFB        +01,exchange        X,Y,Z*SIN (PI/A),Z
                    DEFB        +C0,st-mem-0        X,Y,Z*SIN (PI/A),Z
                    DEFB        +02,delete  X,Y,Z*SIN (PI/A)
                    DEFB        +03,subtract        X, Y - Z*SIN (PI/A)
                    DEFB        +01,exchange        Y - Z*SIN (PI/A), X
                    DEFB        +E0,get-mem-0       Y - Z*SIN (PI/A), X, Z
                    DEFB        +0F,addition        Y - Z*SIN (PI/A), X+Z
                    DEFB        +CO,st-mem-0        (X+Z is copied to mem-0)
                    DEFB        +01,exchange        X+Z, Y - Z*SIN (PI/A)
                    DEFB        +31,duplicate       X+Z, Y-Z*SIN (PI/A), Y-Z*SIN
                                                    (PI/A)
                    DEFB        +E0,get-mem-0       sa,sb,sb,sa
```

```
         DEFB    +01,exchange        sa,sb,sa,sb
         DEFB    +31,duplicate       sa,sb,sa,sb,sb
         DEFB    +E0,get-mem-0       sa,sb,sa,sb,sb,sa
         DEFB    +A0,stk-zero        sa,sb,sa,sb,sb,sa,0
         DEFB    +C1,st-mem-1        (mem-1 is set to zero)
         DEFB    +02,delete          sa,sb,sa,sb,sb,sa
         DEFB    +38,end-calc
```

(Here sa denotes X+Z and sb denotes Y - Z*SIN (PI/A)).

```
         INC     (mem-2-1st)         Incrementing the exponent byte
                                     of mem-2 sets mem-2 to
                                     2*Z*SIN(PI/A).
         CALL    1E94,FIND-INT1      The last value X+Z is moved
         LD      L,A                 from the stack to A and copied
                                     to L.
         PUSH    HL                  It is saved in HL.
         CALL    1E94,FIND-INT1      Y - Z*SIN (PI/A) goes from the
         POP     HL                  stack to A and is copied to H.
         LD      H,A                 HL now holds the initial point.
         LD      (COORDS),HL         It is copied to COORDS.
         POP     BC                  The arc-count is restored.
         JP      2420,DRW-STEPS      The jump is made to DRAW.
```

(The stack now holds X+Z, Y - Z*SIN (PI/A), Y - Z*SIN (PI/A), X+Z).

THE DRAW COMMAND ROUTINE

This routine is entered with the co-ordinates of a point X0, Y0, say, in COORDS. If only two parameters X, Y are given with the DRAW command, it draws an approximation to a straight line from the point X0, Y0 to X0+X, Y0+Y. If a third parameter G is given, it draws an approximation to a circular arc from X0, Y0 to X0+X, Y0+Y turning anti-clockwise through an angle G radians.

The routine has four parts:

I. Just draws a line if only 2 parameters are given or if the diameter of the implied circle is less than 1;
II. Calls CD-PRMS1 at 247D-24B6 to set the first parameters;
III. Sets up the remaining parameters, including the initial displacements for the first arc;
IV. Enters the arc-drawing loop and draws the arc as a series of smaller arcs approximated by straight lines, calling the line-drawing subroutine at 24B7-24FA as necessary.

Two subroutines, CD-PRMS1 and DRAW-LINE, follow the main routine. The above 4 parts of the main routine will now be treated in turn.

i. If there are only 2 parameters, a jump is made to LINE-DRAW at 2477. A line is also drawn if the quantity Z=(ABS X + ABS Y)/ABS SIN(G/2) is less than 1. Z lies between 1 and 1.5 times the diameter of the implied circle. In this section mem-0 is set to SIN (G/2), mem-1 to Y, and mem-5 to G.

```
2382     DRAW       RST     0018,GET-CHAR       Get the current character.
                    CP      +2C                 If it is a comma,
                    JR      Z,238D,DR-3-PRMS    then jump.
                    CALL    1BEE,CHECK-END      Move on to next statement if
                                                checking syntax.
                    JP      2477,LINE-DRAW      Jump to just draw the line.
238D     DR-3-PRMS  RST     0020,NEXT-CHAR      Get next character (the angle).
                    CALL    1C82,EXPT-1NUM      Angle to calculator stack.
                    CALL    1BEE,CHECK-END      Move on to next statement if
                                                checking syntax.
                    RST     0028,FP-CALC        X, Y, G are on the stack.
                    DEFB    +C5,st-mem-5        (G is copied to mem-5)
                    DEFB    +A2,stk-half        X, Y, G, 0.5
                    DEFB    +04,multiply        X, Y, G/2
                    DEFB    +1F,sin             X, Y, SIN (G/2)
                    DEFB    +31,duplicate       X, Y, SIN (G/2), SIN (G/2)
```

		DEFB	+30,not	X, Y, SIN (G/2), (0/1)
		DEFB	+30,not	X, Y, SIN (G/2), (1/0)
		DEFB	+00,jump-true	X, Y, SIN (G/2)
		DEFB	+06,to DR-SIN-NZ	(If SIN (G/2)=0 i.e. G = 2*N*PI
		DEFB	+02,delete	just draw a straight line).
		DEFB	+38,end-calc	X, Y
		JP	2477,LINE-DRAW	Line X0, Y0 to X0+X, Y0+Y.
23A3	DR-SIN-NZ	DEFB	+C0,st-mem-0	(SIN (G/2) is copied to mem-0)
		DEFB	+02,delete	X, Y are now on the stack.
		DEFB	+C1,st-mem-1	(Y is copied to mem-1).
		DEFB	+02,delete	X
		DEFB	+31,duplicate	X, X
		DEFB	+2A,abs	X, X' (X' = ABS X)
		DEFB	+E1,get-mem-1	X, X', Y
		DEFB	+01,exchange	X, Y, X'
		DEFB	+E1,get-mem-1	X, Y, X', Y
		DEFB	+2A,abs	X, Y, X', Y' (Y' = ABS Y)
		DEFB	+0F,addition	X, Y, X'+Y'
		DEFB	+E0,get-mem-0	X, Y, X'+Y', SIN (G/2)
		DEFB	+05,division	X, Y, (X'+Y')/SIN (G/2)=Z', say
		DEFB	+2A,abs	X, Y, Z (Z = ABS Z')
		DEFB	+E0,get-mem-0	X, Y, Z, SIN (G/2)
		DEFB	+01,exchange	X, Y, SIN (G/2), Z
		DEFB	+3D,re-stack	(Z is re-stacked to make sure
		DEFB	+38,end-calc	that its exponent is available).
		LD	A,(HL)	Get exponent of Z.
		CP	+81	If Z is greater than or equal
		JR	NC,23C1,DR-PRMS	to 1, jump.
		RST	0028,FP-CALC	X, Y, SIN (G/2), Z
		DEFB	+02,delete	X, Y, SIN (G/2)
		DEFB	+02,delete	X, Y
		DEFB	+38,end-calc	Just draw the line from X0, Y0
		JP	2477,LINE-DRAW	to X0+X, Y0+Y.

ii. Just calls CD-PRMS1. This subroutine saves in the B register the number of shorter arcs required for the complete arc, viz. A=4*INT (G'*SQR Z/8)+4, where G' = mod G, or 252 if this expression exceeds 252 (as can happen with a large chord and a small angle). So A is 4, 8, 12, ... , up to 252. The subroutine also stores in mem-0 to mem-4 the quantities G/A, SIN (G/2*A), 0, COS (G/A), SIN (G/A).

23C1	DR-PRMS	CALL	247D,CD-PRMS1	The subroutine is called.

iii. Sets up the rest of the parameters as follow. The stack will hold these 4 items, reading up to the top: X0+X and Y0+Y as end of last arc; then X0 and Y0 as beginning of first arc. Mem-0 will hold X0 and mem-5 Y0. Mem-1 and mem-2 will hold the initial displacements for the first arc, U and V; and mem-3 and mem-4 will hold COS (G/A) and SIN (G/A) for use in the arc-drawing loop.

The formulae for U and V can be explained as follows. Instead of stepping along the final chord, of length L, say, with displacements X and Y, we want to step along an initial chord (which may be longer) of length L*W, where W=SIN (G/2*A)/SIN (G/2), with displacements X*W and Y*W, but turned through an angle - (G/2 - G/2*A), hence with true displacements:

U = Y*W*SIN (G/2 - G/2*A) + X*W*COS (G/2 - G/2*A)
Y = Y*W*COS (G/2 - G/2*A) - X*W*SIN (G/2 - G/2*A)

These formulae cam be checked from a diagram, using the normal expansion of COS (P - Q) and SIN (P - Q), where Q = G/2 - G/2*A

23C4		PUSH	BC	Save the arc-counter in B.
		RST	0028,FP-CALC	X,Y,SIN(G/2),Z
		DEFB	+02,delete	X,Y,SIN(G/2)
		DEFB	+E1,get-mem-1	X,Y,SIN(G/2),SIN(G/2*A)
		DEFB	+01,exchange	X,Y,SIN(G/2*A),SIN(G/2)
		DEFB	+05,division	X,Y,SIN(G/2*A)/SIN(G/2)=W
		DEFB	+C1,st-mem-1	(W is copied to mem-1).

```
DEFB    +02,delete          X,Y
DEFB    +01,exchange        Y,X
DEFB    +31,duplicate       Y,X,X
DEFB    +E1,get-mem-1       Y,X,X,W
DEFB    +04,multiply        Y,X,X*W
DEFB    +C2,st-mem-2        (X*W is copied to mem-2).
DEFB    +02,delete          Y,X
DEFB    +01,exchange        X,Y
DEFB    +31,duplicate       X,Y,Y
DEFB    +E1,get-mem-1       X,Y,Y,W
DEFB    +04,multiply        X,Y,Y*W
DEFB    +E2,get-mem-2       X,Y,Y*W,X*W
DEFB    +E5,get-mem-5       X,Y,Y*W,X*W,G
DEFB    +E0,get-mem-0       X,Y,Y*W,X*W,G,G/A
DEFB    +03,subtract        X,Y,Y*W,X*W,G - G/A
DEFB    +A2,stk-half        X,Y,Y*W,X*W,G - G/A, ½
DEFB    +04,multiply        X,Y,Y*W,X*W, G/2 - G/2*A=F
DEFB    +31,duplicate       X,Y,Y*W,X*W, F, F
DEFB    +1F,sin             X,Y,Y*W,X*W, F, SIN F
DEFB    +C5,st-mem-5        (SIN F is copied to mem-5).
DEFB    +02,delete          X,Y,Y*W,X*W,F
DEFB    +20,cos             X,Y,Y*W,X*W, COS F
DEFB    +C0,st-mem-0        (COS F is copied to mem-0).
DEFB    +02,delete          X,Y,Y*W,X*W
DEFB    +C2,st-mem-2        (X*W is copied to mem-2).
DEFB    +02,delete          X,Y,Y*W
DEFB    +C1,st-mem-1        (Y*W is copied to mem-1).
DEFB    +E5,get-mem-5       X,Y,Y*W,SIN F
DEFB    +04,multiply        X,Y,Y*W*SIN F
DEFB    +E0,get-mem-0       X,Y,Y*W*SIN F,X*W
DEFB    +E2,get-mem-2       X,Y,Y*W*SIN F,X*W, COS F
DEFB    +04,multiply        X,Y,Y*W*SIN F,X*W*COS F
DEFB    +0F,addition        X,Y,Y*W*SIN F+X*W*COS F=U
DEFB    +E1,get-mem-1       X,Y,U,Y*W
DEFB    +01,exchange        X,Y,Y*W,U
DEFB    +C1,st-mem-1        (U is copied to mem-1)
DEFB    +02,delete          X,Y,Y*W
DEFB    +E0,get-mem-0       X,Y,Y*W, COS F
DEFB    +04,multiply        X,Y,Y*W*COS F
DEFB    +E2,get-mem-2       X,Y,Y*W*COS F,X*W
DEFB    +E5,get-mem-5       X,Y,Y*W*COS F,X*W, SIN F
DEFB    +04,multiply        X,Y,Y*W*COS F,X*W*SIN F
DEFB    +03,subtract        X,Y,Y*W*COS F - X*W*SIN
                            F = V
DEFB    +C2,st-mem-2        (V is copied to mem-2).
DEFB    +2A,abs             X, Y, V' (V' = ABS V)
DEFB    +E1,get-mem-1       X, Y, V', U
DEFB    +2A,abs             X, Y, V', U' (U' = ABS U)
DEFB    +0F,addition        X, Y, U' + V'
DEFB    +02,delete          X, Y
DEFB    +38,end-calc        (DE now points to U' + V').
LD      A,(DE)              Get exponent of U' + V'
CP      +81                 If U' + V' is less than 1, just
POP     BC                  tidy the stack and draw the line
JP      C,2477,LINE-DRAW    from X0, Y0 to X0+X, Y0+Y.
PUSH    BC                  Otherwise, continue with the
RST     0028,FP-CALC        parameters: X, Y, on the stack.
DEFB    +01,exchange        Y, X
DEFB    +38,end-calc
LD      A,(COORDS-lo)       Get X0 into A and so
CALL    2D28,STACK-A        on to the stack.
RST     0028,FP-CALC        Y, X, X0
```

```
                DEFB    +C0,st-mem-0        (X0 is copied to mem-0).
                DEFB    +0F,addition        Y, X0 + X
                DEFB    +01,exchange        X0+X, Y
                DEFB    +38,end-calc
                LD      A,(COORDS-hi)       Get Y0 into A and so
                CALL    2D28,STACK-A        on to the stack.
                RST     0028,FP-CALC        X0+X, Y, Y0
                DEFB    +C5,st-mem-5        (Y0 is copied to mem-5).
                DEFB    +0F,addition        X0+X, Y0+Y
                DEFB    +E0,get-mem-0       X0+X, Y0+Y, X0
                DEFB    +E5,get-mem-5       X0+X, Y0+Y, X0, Y0
                DEFB    +38,end calc
                POP     BC                  Restore the arc-counter in B.
```

iv. The arc-drawing loop. This is entered at 2439 with the co-ordinates of the starting point on top of the stack, and the initial displacements for the first arc in mem-1 and mem-2. It uses simple trigonometry to ensure that all subsequent arcs will be drawn to points that lie on the same circle as the first two, subtending the same angle at the centre. It can be shown that if 2 points X1, Y1 and X2, Y2 lie on a circle and subtend an angle N at the centre, which is also the origin of co-ordinates, then X2 = X1*COS N - Y1*SIN N, and Y2 = X1*SIN N + Y1*COS N. But because the origin is here at the increments, say Un = Xn+1 - Xn and Vn = Yn+1 - Yn, thus achieving the desired result. The stack is shown below on the (n+1)th pass through the loop, as Xn and Yn are incremented by Un and Vn, after these are obtained from Un-1 and Vn-1. The 4 values on the top of the stack at 2425 are, in DRAW, reading upwards, X0+X, Y0+Y, Xn and Yn but to save space these are not shown until 2439. For the initial values in CIRCLE, see the end of CIRCLE, above. In CIRCLE too, the angle G must be taken to be 2*PI.

```
2420    DRW-STEPS   DEC     B               B counts the passes through the
                                            loop.
                    JR      Z,245F,ARC-END  Jump when B has reached zero.
                    JR      2439,ARC-START  Jump into the loop to start.
2425    ARC-LOOP    RST     0028,FP-CALC    (See text above for the stack).
                    DEFB    +E1,get-mem-1   Un-1
                    DEFB    +31,duplicate   Un-1,Un-1
                    DEBF    +E3,get-mem-3   Un-1,Un-1,COS(G/A)
                    DEFB    +04,multiply    Un-1,Un-1*COS(G/A)
                    DEFB    +E2,get-mem-2   Un-1,Un-1*COS(G/A),Vn-1
                    DEFB    +E4,get-mem-4   Un-1,Un-1*COS(G/A),Vn-1,
                                            SIN(G/A)
                    DEFB    +04,multiply    Un-1,Un-1*COS(G/A),Vn-1*
                                            SIN(G/A)
                    DEFB    +03,subtract    Un-1,Un-1*COS(G/A)-Vn-1*
                                            SIN(G/A)=Un
                    DEFB    +C1,st-mem-1    (Un is copied to mem-1).
                    DEFB    +02,delete      Un-1
                    DEFB    +E4,get-mem-4   Un-1,SIN(G/A)
                    DEFB    +04,multiply    Un-1*SIN(G/A)
                    DEFB    +E2,get-mem-2   Un-1*SIN(G/A),Vn-1
                    DEFB    +E3,get-mem-3   Un-1*SIN(G/A),Vn-1,COS(G/A)
                    DEFB    +04,multiply    Un-1*SIN(G/A),Vn-1*COS(G/A)
                    DEFB    +0F,addition    Un-1*SIN(G/A)+Vn-1*COS
                                            (G/A)=Vn
                    DEFB    +C2,st-mem-2    (Vn is copied to mem-2).
                    DEFB    +02,delete      (As noted in the text, the stack
                    DEFB    +38,end-calc    in fact holds X0+X,Y0+Y, Xn
                                            and Yn).
2439    ARC-START   PUSH    BC              Save the arc-counter.
                    RST     0028,FP-CALC    X0+X, Y0+y, Xn, Yn
                    DEFB    +C0,st-mem-0    (Yn is copied to mem-0).
                    DEFB    +02,delete      X0+X, Y0+Y, Xn
                    DEFB    +E1,get-mem-1   X0+X, Y0+Y, Xn, Un
                    DEFB    +0F,addition    X0+X, Y0+Y, Xn+Un = Xn+1
```

```
                DEFB    +31,duplicate       X0+X, Y0+Y, Xn+1, Xn+1
                DEFB    +38,end-calc        Next Xn', the approximate
                                            value of Xn reached by
                                            the line-drawing subroutine
                LD      A,(COORDS-lo)       is copied to A
                CALL    2D28,STACK-A        and hence to the stack.
                RST     0028,FP-CALC        X0+X,Y0+Y,Xn+1,Xn'
                DEFB    +03,subtract        X0+X,Y0+Y,Xn+1,Xn+1,Xn'
                                            - Xn' = Un'
                DEFB    +E0,get-mem-0       X0+X,Y0+Y,Xn+1,Un',Yn
                DEFB    +E2,get-mem-2       X0+X,Y0+Y,Xn+1,Un',Yn,Vn
                DEFB    +0F,addition        X0+X,Y0+Y,Xn+1,Un',Yn +
                                            Vn = Yn+1
                DEFB    +C0,st-mem-0        (Yn+1 is copied to mem-0).
                DEFB    +01,exchange        X0+X,Y0+Y,Xn+1,Yn+1,Un'
                DEFB    +E0,get-mem-0       X0+X,Y0+Y,Xn+1,Yn+1,
                                            Un',Yn+1
                DEFB    +38,end-calc
                LD      A,(COORDS-hi)       Yn', approximate like Xn', is
                CALL    2D28,STACK-A        copied to A and hence to the
                                            stack.
                RST     0028,FP-CALC        X0+X,Y0+Y,Xn+1,Yn+1,
                                            Un',Yn+1,Yn'
                DEFB    +03,subtract        X0+X,Y0+Y,Xn+1,Yn+1,
                                            Un',Vn'
                DEFB    +38,end-calc
                CALL    24B7,DRAW-LINE      The next 'arc' is drawn.
                POP     BC                  The arc-counter is restored.
                DJNZ    2425,ARC-LOOP       Jump if more arcs to draw.
245F    ARC-END RST     0028,FP-CALC        The co-ordinates of the end
                DEFB    +02,delete          of the last arc that was drawn
                DEFB    +02,delete          are now deleted from the stack.
                DEFB    +01,exchange        Y0+Y, X0+X
                DEFB    +38,end-calc
                LD      A,(COORDS-lo)       The X-co-ordinate of the end of
                CALL    2D28,STACK-A        the last arc that was drawn, say
                RST     0028,FP-CALC        Xz', is copied to the stack.
                DEFB    +03,subtract        Y0+Y, X0+X - Xz'
                DEFB    +01,exchange        X0+X - Xz', Y0+Y
                DEFB    +38,end-calc
                LD      A,(COORDS-hi)       The Y-co-ordinate is obtained.
                CALL    2D28,STACK-A
                RST     0028,FP-CALC        X0+X - Xz', Y0+Y, Yz'
                DEFB    +03,subtract        X0+X - Xz', Y0+Y - Yz'
                DEFB    +38,end-calc
2477    LINE-DRAW CALL  24B7,DRAW-LINE      The final arc is drawn to reach
                                            X0+X, Y0+Y (or close the
                                            circle).
                JP      0D4D,TEMPS          Exit, setting temporary colours.
```

THE 'INITIAL PARAMETERS' SUBROUTINE

This subroutine is called by both CIRCLE and DRAW to set their initial parameters. It is called by CIRCLE with X, Y and the radius Z on the top of the stack, reading upwards. It is called by DRAW with its own X, Y, SIN (G/2) and Z, as defined in DRAW i. above, on the top of the stack. In what follows the stack is only shown from Z upwards.
The subroutine returns in B the arc-count A as explained in both CIRCLE and DRAW above, and in mem-0 to mem-5 the quantities G/A, SIN (G/2*A), 0, COS (G/A), SIN (G/A) and G. For a circle, G must be taken to be equal to 2*PI.

```
247D    CD-PRMS1 RST    0028,FP-CALC        Z
                DEFB    +31,duplicate       Z, Z
                DEFB    +28,sqr             Z, SQR Z
                DEFB    +34,stk-data        Z, SQR Z, 2
```

```
                DEFB    +32,exponent +82
                DEFB    +00,(+00,+00,+00)
                DEFB    +01,exchange        Z, 2, SQR Z
                DEFB    +05,division        Z, 2/SQR Z
                DEFB    +E5,get-mem-5       Z, 2/SQR Z, G
                DEFB    +01,exchange        Z, G, 2/SQR Z
                DEFB    +05,division        Z, G*SQR Z/2
                DEFB    +2A,abs             Z, G'*SQR Z/2 (G' = mod G)
                DEFB    +38,end-calc        Z, G'*SQR Z/2 = A1, say
                CALL    2DD5,FP-TO-A        A1 to A from the stack, if
                                            possible.
                JR      C,2495,USE-252      If A1 rounds to 256 or more,
                                            use 252.
                AND     +FC                 4*INT (A1/4) to A.
                ADD     A,+04               Add 4, giving the arc-count A.
                JR      NC,2497,DRAW-SAVE   Jump if still under 256.
2495    USE-252 LD      A,+FC               Here, just use 252 decimal.
2497    DRAW-SAVE PUSH  AF                  Now save the arc-count.
                CALL    2D28,STACK-A        Copy it to calculator stack too.
                RST     0028,FP-CALC        Z, A
                DEFB    +E5,get-mem-5       Z, A, G
                DEFB    +01,exchange        Z, G, A
                DEFB    +05,division        Z, G/A
                DEFB    +31,duplicate       Z,G/A, G/A
                DEFB    +1F,sin             Z, G/A, SIN (G/A)
                DEFB    +C4,st-mem-4        (SIN (G/A) is copied to mem-4).
                DEFB    +02,delete          Z, G/A
                DEFB    +31,duplicate       Z, G/A, G/A
                DEFB    +A2,stk-half        Z, G/A, G/A, 0.5
                DEFB    +04,multiply        Z, G/A, G/2*A
                DEFB    +1F,sin             Z, G/A, SIN (G/2*A)
                DEFB    +C1,st-mem-1        (SIN (G/2*A) is copied to
                                            mem-1).
                DEFB    +01,exchange        Z, SIN (G/2*A), G/A
                DEFB    +C0,st-mem-0        (G/A is copied to mem-0).
                DEFB    +02,delete          Z, SIN (G/2*A) = S
                DEFB    +31,duplicate       Z, S, S
                DEFB    +04,multiply        Z, S*S
                DEFB    +31,duplicate       Z, S*S, S*S
                DEFB    +0F,addition        Z, 2*S*S
                DEFB    +A1,stk-one         Z, 2*S*S, 1
                DEFB    +03,subtract        Z, 2*S*S - 1
                DEFB    +1B,negate          Z, 1 - 2*S*S = COS (G/A)
                DEFB    +C3,st-mem-3        (COS (G/A) is copied to mem-3).
                DEFB    +02,delete          Z
                DEFB    +38,end-calc
                POP     BC                  Restore the arc-count to B.
                RET                         Finished.
```

THE LINE-DRAWING SUBROUTINE

This subroutine is called by DRAW to draw an approximation to a straight line from the point X0, Y0 held in COORDS to the point X0+X, Y0+Y, where the increments X and Y are on the top of the calculator stack. The subroutine was originally intended for the ZX80 and ZX81 8K ROM, and it is described in a BASIC program on page 121 of the ZX81 manual. It is also illustrated here in the Circle program in the appendix.

The method is to intersperse as many horizontal or vertical steps as are needed among a basic set of diagonal steps, using an algorithm that spaces the horizontal or vertical steps as evenly as possible.

```
24B7    DRAW-LINE CALL  2307,STK-TO-BC      ABS Y to B; ABS X to C;
                                            SGN Y to D; SGN X to E.
                LD      A,C                 Jump if ABS X is greater than
                CP      B                   or equal to ABS Y, so that the
```

```
                    JR      NC,24C4,DL-X-GE-Y   smaller goes to L, and the
                    LD      L,C                 larger (later) goes to H.
                    PUSH    DE                  Save diag. step (±1,±1) in DE.
                    XOR     A                   Insert a vertical step (±1, 0)
                    LD      E,A                 into DE (D holds SGN Y).
                    JR      24CB,DL-LARGER      Now jump to set H.
24C4    DL-X-GE-Y   OR      C                   Return if ABS X and ABS Y
                    RET     Z                   are both zero.
                    LD      L,B                 The smaller (ABS Y here) goes
                                                to L.
                    LD      B,C                 ABS X to B here, for H.
                    PUSH    DE                  Save the diagonal step here too.
                    LD      D,+00               Hor. step (0, ±1) to DE here.
24CB    DL-LARGER   LD      H,B                 Larger of ABS X, ABS Y to H
                                                now.
```

The algorithm starts here. The larger of ABS X and ABS Y, say H, is put into A and reduced to INT (H/2). The H - L horizontal or vertical steps and L diagonal steps are taken (where L is the smaller of ABS X and ABS Y) in this way: L is added to A; if A now equals or exceeds H, it is reduced by H and a diagonal step is taken; otherwise a horizontal or vertical step is taken. This is repeated H times (B also holds H). Note that meanwhile the exchange registers H' and L' are used to hold COORDS.

```
                    LD      A,B                 B to A as well as to H.
                    RRA                         A starts at INT (H/2).
24CE    D-L-LOOP    ADD     A,L                 L is added to A.
                    JR      C,24D4,D-L-DIAG     If 256 or more, jump - diag.
                                                step.
                    CP      H                   If A is less than H, jump for
                    JR      C,24DB,D-L-HR-VT    horizontal or vertical step.
24D4    D-L-DIAG    SUB     H                   Reduce A by H.
                    LD      C,A                 Restore it to C.
                    EXX                         Now use the exchange resisters.
                    POP     BC                  Diag. step to B'C'.
                    PUSH    BC                  Save it too.
                    JR      24DF,D-L-STEP       Jump to take the step.
24DB    D-L-HR-VT   LD      C,A                 Save A (unreduced) in C.
                    PUSH    DE                  Step to stack briefly.
                    EXX                         Get exchange registers.
                    POP     BC                  Step to B'C' now.
24DF    D-L-STEP    LD      HL,(COORDS)         Now take the step: first,
                                                COORDS to H'L' as the start
                                                point.
                    LD      A,B                 Y-step from B' to A.
                    ADD     A,H                 Add in H'.
                    LD      B,A                 Result to B'  .
                    LD      A,C                 Now the X-step; it will be tested
                    INC     A                   for range (Y will be tested in
                                                PLOT).
                    ADD     A,L                 Add L' to C' in A, jump on
                    JR      C,24F7,D-L-RANGE    carry for further test.
                    JR      Z,24F9,REPORT-B     Zero after no carry denotes
                                                X-position -1, out of range.
24EC    D-L-PLOT    DEC     A                   Restore true value to A.
                    LD      C,A                 Value to C' for plotting.
                    CALL    22E5,PLOT-SUB       Plot the step.
                    EXX                         Restore main registers.
                    LD      A,C                 C back to A to continue
                                                algorithm.
                    DJNZ    24CE,D-L-LOOP       Loop back for 8 steps (i.e. H
                                                steps).
                    POP     DE                  Clear machine stack.
                    RET                         Finished.
```

24F7	D-L-RANGE	JR	Z,24EC,D-L-PLOT	Zero after carry denotes X. position 255, in range.

Report B - Integer out of range

24F9	REPORT-B	RST DEFB	0008,ERROR-1 +0A	Call the error handling routine.

EXPRESSION EVALUATION

THE 'SCANNING' SUBROUTINE

This subroutine is used to produce an evaluation result of the 'next expression'.

The result is returned as the 'last value' on the calculator stack. For a numerical result, the last value will be the actual floating point number. However, for a string result the last value will consist of a set of parameters. The first of the five bytes is unspecified, the second and third bytes hold the address of the start of the string and the fourth and fifth bytes hold the length of the string.

Bit 6 of FLAGS is set for a numeric result and reset for a string result.

When a next expression consists of only a single operand, e.g. ... A ..., ... RND ..., ... A$ (4, 3 TO 7) ... , then the last value is simply the value that is obtained from evaluating the operand.

However when the next expression contains a function and an operand, e.g. ... CHR$ A..., ... NOT A ... , SIN 1 ..., the operation code of the function is stored on the machine stack until the last value of the operand has been calculated. This last value is then subjected to the appropriate operation to give a new last value.

In the case of there being an arithmetic or logical operation to be performed, e.g. ... A+B ... , A*B ..., ... A=B ... , then both the last value of the first argument and the operation code have to be kept until the last value of the second argument has been found. Indeed the calculation of the last value of the second argument may also involve the storing of last values and operation codes whilst the calculation is being performed.

It can therefore be shown that as a complex expression is evaluated, e.g. ... CHR$ (T+A - 26*INT ((T+A)/26)+65)..., a hierarchy of operations yet to be performed is built up until the point is reached from which it must be dismantled to produce the final last value.

Each operation code has associated with it an appropriate priority code and operations of higher priority are always performed before those of lower priority.

The subroutine begins with the A register being set to hold the first character of the expression and a starting priority marker - zero - being put on the machine stack.

```
24FB    SCANNING    RST     0018,GET-CHAR       The first character is fetched.
                    LD      B,+00               The starting priority marker.
                    PUSH    BC                  It is stacked.
24FF    S-LOOP-1    LD      C,A                 The main re-entry point.
                    LD      HL,+2596            Index into scanning function
                    CALL    16DC,INDEXER        table with the code in C.
                    LD      A,C                 Restore the code to A.
                    JP      NC,2684,S-ALPHNUM   Jump if code not found in table.
                    LD      B,+00               Use the entry found in the table
                    LD      C,(HL)              to build up the required address
                    ADD     HL,BC               in HL, and jump to it.
                    JP      (HL)
```

Four subroutines follow; they are called by routines from the scanning function table. The first one, the 'scanning quotes subroutine', is used by S-QUOTE to check that every string quote is matched by another one.

```
250F    S-QUOTE-S   CALL    0074,CH-ADD+1       Point to the next character.
                    INC     BC                  Increase the length count by
                                                one.
                    CP      +0D                 Is it a carriage return?
                    JP      Z, 1C8A,REPORT-C    Report the error if so.
                    CP      +22                 Is it another ""?
                    JR      NZ,250F,S-QUOTE-S   Loop back if it is not.
                    CALL    0074,CH-ADD+1       Point to next character; set zero
                    CP      +22                 flag if it is another "".
                    RET                         Finished.
```

The next subroutine, the 'scanning: two co-ordinates' subroutine, is called by S-SCREEN$, S-ATTR and S-POINT to make sure the required two co-ordinates are given in their proper form.

```
2522    S-2-COORD   RST     0020, NEXT-CHAR     Fetch the next character.
                    CP      +28                 Is it a '('?
```

```
                    JR      NZ,252D,S-RPORT-C   Report the error if it is not.
                    CALL    1C79,NEXT-2NUM      Co-ordinates to calculator stack.
                    RST     0018,GET-CHAR       Fetch the current character.
                    CP      +29                 Is it a ')'?
252D    S-RPORT-C   JP      NZ,1C8A,REPORT-C    Report the error if it is not.
```

THE 'SYNTAX-Z' SUBROUTINE

At this point the 'SYNTAX-Z' subroutine is interpolated. It is called 32 times, with a saving of just one byte each call. A simple test of bit 7 of FLAGS will give the zero flag reset during execution and set during syntax checking.
i.e. SYNTAX gives Z set.

```
2530    SYNTAX-Z    BIT     7,(FLAGS)           Test bit 7 of FLAGS.
                    RET                         Finished.
```

The next subroutine is the 'scanning SCREEN$ subroutine', which is used by S-SCREENS$ to find the character that appears at line x, column y of the screen. It only searches the character set 'pointed to' to CHARS.

Note: This is normally the characters +20 (space) to +7F (©) although the user can alter CHARS to match for other characters, including user-defined graphics.

```
2535    S-SCRN$-S   CALL    2307,STK-TO-BC      x to C, y to B; 0<=x<23
                    LD      HL,(CHARS)          decimal; O<=y<=31 decimal.
                    LD      DE,+0100            CHARS plus 256 decimal gives
                    ADD     HL,DE               HL pointing to the character set.
                    LD      A,C                 x is copied to A.
                    RRCA                        The number 32 (decimal) * (x
                    RRCA                        mod 8) + y is formed in A and
                                                copied to E.
                    RRCA                        This is the low byte of the
                    AND     +E0                 required screen address.
                    XOR     B
                    LD      E,A
                    LD      A,C                 x is copied to A again
                    AND     +18                 Now the number 64 (decimal) +
                    XOR     +40                 8*INT (x/8) is inserted into D.
                    LD      D,A                 DE now holds the screen address.
                    LD      B,+60               B counts the 96 characters.
254F    S-SCRN-LP   PUSH    BC                  Save the count.
                    PUSH    DE                  And the screen pointer.
                    PUSH    HL                  And the character set pointer.
                    LD      A,(DE)              Get first row of screen character.
                    XOR     (HL)                Match with row from character
                                                set.
                    JR      Z,255A,S-SC-MTCH    Jump if direct match found.
                    INC     A                   Now test for match with inverse
                                                character (get +00 in A from
                                                +FF).
                    JR      NZ,2573,S-SCR-NXT   Jump if neither match found.
                    DEC     A                   Restore +FF to A.
255A    S-SC-MTCH   LD      C,A                 Inverse status (+00 or +FF) to C.
                    LD      B,+07               B counts through the other 7
                                                rows.
255D    S-SC-ROWS   INC     D                   Move DE to next row (add 256
                                                dec.).
                    INC     HL                  Move HL to next row (i.e. next
                                                byte).
                    LD      A,(DE)              Get the screen row.
                    XOR     (HL)                Match with row from the ROM.
                    XOR     C                   Include the inverse status.
                    JR      NZ,2573,S-SCR-NXT   Jump if row fails to match.
                    DJNZ    255D,S-SC-ROWS      Jump back till all rows done.
                    POP     BC                  Discard character set pointer.
                    POP     BC                  And screen pointer.
```

```
                POP     BC              Final count to BC.
                LD      A,+80           Last character code in set plus
                                        one.
                SUB     B               A now holds required code.
                LD      BC,+0001        One space is now needed in the
                                        work space.
                RST     0030,BC-SPACES  Make the space.
                LD      (DE),A          Put the character into it.
                JR      257D,S-SCR-STO  Jump to stack the character.
2573  S-SCR-NXT POP     HL              Restore character set pointer.
                LD      DE,+0008        Move it on 8 bytes, to the next
                ADD     HL,DE           character in the set.
                POP     DE              Restore the screen pointer.
                POP     BC              And the counter.
                DJNZ    254F,S-SCRN-LP  Loop back for the 96 characters.
                LD      C,B             Stack the empty string (Length
                                        zero).
257D  S-SCR-STO JP 2AB2,STK-STO-$       Jump to stack the matching
                                        character, or the null string if
                                        no match is found.
```

Note: This exit, via STK-STO-$, is a mistake as it leads to 'double storing' of the string result (see S-STRING, 25DB). The instruction line should be 'RET'.

The last of these four subroutines is the 'scanning attributes subroutine'. It is called by S-ATTR to return the value of ATTR (x,y) which codes the attributes of line x, column y on the television screen.

```
2580  S-ATTR-S  CALL    2307,STK-TO-BC  x to C, y to B. Again, 0<=x<=23
                LD      A,C             decimal; 0<=y<=31 decimal.
                RRCA                    x is copied to A and the number
                RRCA                    32 (decimal)*x (mod 8)+y is
                RRCA                    formed in A and copied to L.
                LD      C,A             32*x(mod 8)+INT (x/8) is also
                AND     +E0             copied to C.
                XOR     B
                LD      L,A             L holds low byte of attribute
                                        address.
                LD      A,C             32*x(mod 8)+INT (x/8) is
                                        copied to A.
                AND     +03             88 (decimal)+INT (x/8) is
                XOR     +58             formed in A and copied to H.
                LD      H,A             H holds high byte of attribute
                                        address.
                LD      A,(HL)          The attribute byte is copied to
                                        A.
                JP      2D28,STACK-A    Exit, stacking the required byte.
```

THE SCANNING FUNCTION TABLE

This table contains 8 functions and 4 operators. It thus incorporates 5 new Spectrum functions and provides a neat way of accessing some functions and operators which already existed on the ZX81.

location	code	offset	name	address of handling routine
2596	22	1C	S-QUOTE	25B3
2598	28	4F	S-BRACKET	25E8
259A	2E	F2	S-DECIMAL	268D
259C	2B	12	S-U-PLUS	25AF
259E	A8	56	S-FN	25F5
25A0	A5	57	S-AND	25F8
25A2	A7	84	S-PI	2627
25A4	A6	8F	S-INKEY$	2634
25A6	C4	E6	S-BIN (EQU. S-DECIMAL)	268D
25A8	AA	BF	S-SCREEN$	2668
25AA	AB	C7	S-ATTR	2672

25AC	A9 CE	S-POINT	267B	
25AE	00		End-marker	

THE SCANNING FUNCTION ROUTINES

25AF	S-U-PLUS	RST	0020,NEXTCHAR	For unary plus, simply move on
		JP	24FF,S-LOOP-1	to the next character and jump back to the main re-entry of SCANNING.

The 'scanning QUOTE routine': This routine deals with string quotes, whether simple like "name" or more complex like "a ""white"" lie" or the seemingly redundant VAL$ """"a"""".

25B3	S-QUOTE	RST	0018,GET-CHAR	Fetch the current character.
		INC	HL	Point to the start of the string.
		PUSH	HL	Save the start address.
		LD	BC,+0000	Set the length to zero.
		CALL	250F,S-QUOTE-S	Call the "matching" subroutine.
		JR	NZ,25D9,S-Q-PRMS	Jump if zero reset - no more quotes.
25BE	S-Q-AGAIN	CALL	250F,S-QUOTE-S	Call it again for a third quote.
		JR	Z,25BE,S-Q-AGAIN	And again for the fifth, seventh etc.
		CALL	2530,SYNTAX-Z	If testing syntax, jump to reset
		JR	Z,25D9,S-Q-PRMS	bit 6 of FLAGS and to continue scanning.
		RST	0030,BC-SPACES	Make space in the work space for the string and the terminating quote.
		POP	HL	Get the pointer to the start.
		PUSH	DE	Save the pointer to the first space.
25CB	S-Q-COPY	LD	A,(HL)	Get a character from the string.
		INC	HL	Point to the next one.
		LD	(DE),A	Copy last one to work space.
		INC	DE	Point to the next space.
		CP	+22	Is last character a ""?
		JR	NZ,25CB,S-Q-COPY	If not, jump to copy next one.
		LD	A,(HL)	But if it was, do not copy next
		INC	HL	one; if next one is a "", jump
		CP	+22	to copy the one after it;
		JR	Z,25CB,S-Q-COPY	otherwise, finished with copying.
25D9	S-Q-PRMS	DEC	BC	Get true length to BC.

Note that the first quote was not counted into the length; the final quote was, and is discarded now. Inside the string, the first, third, fifth, etc., quotes were counted in but the second, fourth, etc., were not.

		POP	DE	Restore start of copied string.
25DB	S-STRING	LD	HL,+5C3B	This is FLAGS; this entry point
		RES	6,(HL)	is used whenever bit 6 is to be
		BIT	7,(HL)	reset and a string stacked if exe-
		CALL	NZ,2AB2,STK-STO-S	cuting a line. This is done now.
		JP	2712,S-CONT-2	Jump to continue scanning the line.

Note that in copying the string to the work space, every two pairs of string quotes inside the string ("") have been reduced to one pair of string quotes(").

25E8	S-BRACKET	RST 0020,NEXT-CHAR		The 'scanning BRACKET
		CALL	24FB,SCANNING	routine' simply gets the
		CP	+29	character and calls SCANNING recursively.
		JP	NZ,1C8A,REPORT-C	Report the error if no matching
		RST	0020,NEXT-CHAR	bracket; then continue scanning.

```
                JP      2712,S-CONT-2
25F5    S-FN    JP      27BD,S-FN-SBRN The 'scanning FN routine'.
```

This routine, for user-defined functions, just jumps to the 'scanning FN subroutine'.

```
25F8    S-RND   CALL    2530,SYNTAX-Z   Unless syntax is being checked,
                JR      Z,2626,S-RND-END jump to calculate a random
                                        number.
                LD      BC,(SEED)       Fetch the current value of
                                        SEED.
                CALL    2D2B,STACK-BC   Put it on the calculator stack.
                RST     0028,FP-CALC    Now use the calculator,
                DEFB    +A1,stk-one     The 'last value' is now
                DEFB    +0F,addition    SEED+1.
                DEFB    +34,stk-data    Put the decimal number 75
                DEFB    +37,exponent+87 on the calculator stack.
                DEFB    +16,(+00,+00,+00)
                DEFB    +04,multiply    'last value' (SEED+1)*75.
                DEFB    +34,stk-data    See STACK LITERALS to see
                DEFB    +80,(four bytes) how bytes are expanded so as to
                DEFB    +41,exponent +91 put the decimal number 65537
                DEFB    +00,+00,+80,(+00) on the calculator stack.
                DEFB    +32,n-mod-m     Divide (SEED+1)*75 by 65537
                                        to give a 'remainder' and an
                                        'answer'.
                DEFB    +02,delete      Discard the 'answer'.
                DEFB    +A1,stk-one     The 'last value' is now
                DEFB    +03,subtract    'remainder' - 1.
                DEFB    +31,duplicate   Make a copy of the 'last value'.
                DEFB    +38,end-calc    The calculation is finished.
                CALL    2DA2,FP-TO-BC   Use the 'last value' to give the
                LD      (SEED),BC       new value for SEED.
                LD      A,(HL)          Fetch the exponent of 'last
                                        value'.
                AND     A               Jump forward if the exponent is
                JR      Z,2625,S-RND-END zero.
                SUB     +10             Reduce the exponent, i.e. divide
                LD      (HL),A          'last value' by 65536 to give the
                                        required 'last value'.
2625    S-RND-END JR    2630,S-PI-END   Jump past the 'PI' routine.
```

The 'scanning-PI routine': unless syntax is being checked the value of 'PI' is calculated and forms the 'last value' on the calculator stack.

```
2627    S-PI    CALL    2530,SYNTAX-Z   Test for syntax checking.
                JR      Z,2630,S-PI-END Jump if required.
                RST     0028,FP-CALC    Now use the calculator.
                DEFB    +A3,stk-pi/2    The value of PI/2 is put on the
                DEFB    +3B,end-calc    calculator stack as the 'last
                                        value'.
                INC     (HL)            The exponent is incremented
                                        thereby doubling the 'last value'
                                        giving PI.
2630    S-PI-END RST    0020,NEXT-CHAR  Move on to the next character.
                JP      26C3,S-NUMERIC  Jump forward.
2634    S-INKEY$ LD     BC,+105A        Priority +10 hex, operation
                RST     0020,NEXT-CHAR  code +5A for the 'read-in'
                                        subroutine.
                CP      +23             If next char. is '#', jump.
                JP      Z,270D,S-PUSH-PO There will be a numerical
                                        argument.
                LD      HL,+5C3B        This is FLAGS.
                RES     6,(HL)          Reset bit 6 for a string result.
                BIT     7,(HL)          Test for syntax checking.
```

```
                    JR      Z,2665,S-INK$-EN    Jump if required.
                    CALL    028E,KEY-SCAN       Fetch a key-value in DE.
                    LD      C,+00               Prepare empty string; stack it if
                    JR      NZ,2660,S-IK$-STK   too many keys pressed.
                    CALL    031E,K-TEST         Test the key value; stack empty
                    JR      NC,2660,S-IK$-STK   string if unsatisfactory.
                    DEC     D                   +FF to D for L made (bit 3 set).
                    LD      E,A                 Key-value to E for decoding.
                    CALL    0333,K-DECODE       Decode the key-value.
                    PUSH    AF                  Save the ASCII value briefly.
                    LD      BC,+0001            One space is needed in the work
                                                space.
                    RST     0030,BC-SPACES      Make it now.
                    POP     AF                  Restore the ASCII value.
                    LD      (DE),A              Prepare to stack it as a string.
                    LD      C,+01               Its length is one.
2660    S-IK$-STK   LD      B,+00               Complete the length parameter.
                    CALL    2AB2,STK-STO-$      Stack the required string.
2665    S-INK$-EN   JP      2712,S-CONT-2       Jump forward.
2668    S-SCREEN$   CALL    2522,S-2-COORD      Check that 2 co-ordinates are
                                                given.
                    CALL    NZ,2535,S-SCRN$-S   Call the subroutine unless
                    RST     0020,NEXT-CHAR      checking syntax; then get next
                    JP      25DB,S-STRING       character and jump back.
2672    S-ATTR      CALL    2522,5-2-COORD      Check that 2 co-ordinates are
                                                given.
                    CALL    NZ,2580,S-ATTR-S    Call the subroutine unless
                    RST     0020,NEXT-CHAR      checking syntax; then get the
                    JR      26C3,S-NUMERIC      next character and jump
                                                forward.
267B    S-POINT     CALL    2522,S-2-COORD      Check that 2 co-ordinates are
                                                given.
                    CALL    NZ,22CB,POINT-SUB   Call the subroutine unless
                    RST     0020,NEXT-CHAR      checking syntax; then get the
                    JR      26C3,S-NUMERIC      next character and jump
                                                forward.
2684    S-ALPHNUM   CALL    2C88,ALPHANUM       Is the character alphanumeric?
                    JR      NC,26DF,S-NEGATE    Jump if not a letter or a digit.
                    CP      +41                 Now jump if it a letter;
                    JR      NC,26C9,S-LETTER    otherwise continue on into
                                                S-DECIMAL.
```

The 'scanning DECIMAL routine' which follows deals with a decimal point or a number that starts with a digit. It also takes care of the expression 'BIN', which is dealt with in the 'decimal to floating-point' subroutine.

```
268D    S-DECIMAL   CALL    2530,SYNTAX-Z       Jump forward if a line is
        (EQU. S-BIN) JR     NZ,2685,S-STK-DEC   being executed.
```

The action taken is now very different for syntax checking and line execution. If syntax is being checked then the floating-point form has to be calculated and copied into the actual BASIC line. However when a line is being executed the floating-point form will always be available so it is copied to the calculator stack to form a 'last value'.

During syntax checking:

```
                    CALL    2C9B,DEC-TO-FP      The floating-point form is
                                                found.
                    RST     0018,GET-CHAR       Set HL to point one past the
                                                last digit.
                    LD      BC,+0006            Six locations are required.
                    CALL    1655,MAKE-ROOM      Make the room in the BASIC
                                                line.
                    INC     HL                  Point to the first free space.
                    LD      (HL),+0E            Enter the number marker code.
                    INC     HL                  Point to the second location.
                    EX      DE,HL               This pointer is wanted in DE.
```

```
                    LD      HL,(STKEND)     Fetch the 'old' STKEND.
                    LD      C,+05           There are 5 bytes to move.
                    AND     A               Clear the carry flag.
                    SBC     HL,BC           The 'new' STKEND='old'
                                            STKEND -5.
                    LD      (STKEND),HL     Move the floating-point number
                    LDIR                    from the calculator stack to
                                            the line.
                    EX      DE,HL           Put the line pointer in HL.
                    DEC     HL              Point to the last byte added.
                    CALL    0077,TEMP-PTR1  This sets CH-ADD.
                    JR      26C3,S-NUMERIC  Jump forward.
```

During line execution:

```
26B5  S-STK-DEC   RST     0018,GET-CHAR     Get the current character.
26B6  S-SD-SKIP   INC     HL                Now move on to the next
                  LD      A,(HL)            character in turn until
                  CP      +0E               the number marker code
                  JR      NZ,26B6,S-SD-SKIP is found.
                  INC     HL                Point to the first byte of the
                                            number.
                  CALL    33B4,STACK-NUM    Move the floating-point number.
                  LD      (CH-ADD),HL       Set CH-ADD.
```

A numeric result has now been identified, coming from RND, PI, ATTR, POINT or a decimal number, therefore bit 6 of FLAGS must be set.

```
26C3  S-NUMERIC   SET     6,(FLAGS)         Set the numeric marker flag.
                  JR      26DD,S-CONT-1     Jump forward.
```

THE SCANNING VARIABLE ROUTINE

When a variable name has been identified a call is made to LOOK-VARS which looks through those variables that already exist in the variables area (or in the program area at DEF FN statements for a user-defined function FN). If an appropriate numeric value is found then it is copied to the calculator stack using STACK-NUM. However a string or string array entry has to have the appropriate parameters passed to the calculator stack by the STK-VAR subroutine (or in the case of a user-defined function, by the STK-F-ARG subroutine as called from LOOK-VARS).

```
26C9  S-LETTER    CALL    28B2,LOOK-VARS    Look in the existing variables
                                            for the matching entry.
                  JP      C,1C2E,REPORT-2   An error is reported if there is
                                            no existing entry.
                  CALL    Z,2996,STK-VARS   Stack the parameters of the
                                            string entry/return numeric
                                            element base address.
                  LD      A,(FLAGS)         Fetch FLAGS.
                  CP      +C0               Test bits 6 and 7 together.
                  JR      C,26DD,S-CONT-1   One or both bits are reset.
                  INC     HL                A numeric value is to be stacked.
                  CALL    33B4,STACK-NUM    Move the number.
26DD  S-CONT-1    JR      2712,S-CONT-2     Jump forward.
```

The character is tested against the code for '-', thus identifying the 'unary minus' operation.

Before the actual test the B register is set to hold the priority +09 and the C register the operation code +D8 that are required for this operation.

```
26DF  S-NEGATE    LD      BC,+09DB          Priority +09, operation code
                                            +D8.
                  CP      +2D               Is it a '-'?
                  JR      Z,270D,S-PUSH-PO  Jump forward if it is 'unary
                                            minus'.
```

Next the character is tested against the code for 'VAL$', with priority 16 decimal and operation code 18 hex.

```
                    LD      BC,+1018        Priority 16 dec, operation code
                                            +18 hex.
                    CP      +AE             Is it 'VAL$'?
                    JR      Z,270D,S-PUSH-PO Jump forward if it is 'VAL$'.
```

The present character must now represent one of the functions CODE to NOT, with codes +AF to +C3.

```
                    SUB     +AF             The range of the functions is
                                            changed from +AF to +C3 to
                                            range +00 to +14 hex.
                    JP      C,1C8A,REPORT-C Report an error if out of range.
```

The function 'NOT' is identified and dealt with separately from the others.

```
                    LD      BC,+04F0        Priority +04, operation code
                                            +F0.
                    CP      +14             Is it the function 'NOT'?
                    JR      Z,270D,S-PUSH-PO Jump if it is so.
                    JP      NC,1C8A,REPORT-C Check the range again.
```

The remaining functions have priority 16 decimal. The operation codes for these functions are now calculated. Functions that operate on strings need bit 6 reset and functions that give string results need bit 7 reset in their operation codes.

```
                    LD      B,+10           Priority 16 decimal.
                    ADD     A,+DC           The function range is now +DC
                                            +EF.
                    LD      C,A             Transfer the operation code.
                    CP      +DF             Separate CODE, VAL and LEN
                    JR      NC,2707.S-NO-TO-S which operate on strings to give
                    RES     6,C             numerical results.
2707    S-NO-TO-S   CP      +EE             Separate STR$ and CHR$
                    JR      C,2700,S-PUSH-PO which operate on numbers to
                                            give string results.
                    RES     7,C             Mark the operation codes.
                                            The other operation codes have
                                            bits 6 and 7 both set.
```

The priority code and the operation code for the function being considered are now pushed on to the machine stack. A hierarchy of operations is thereby built up.

```
270D    S-PUSH-PO   PUSH    BC              Stack the priority and operation
                    RST     0020,NEXT-CHAR  codes before moving on to
                    JP      24FF,S-LOOP-1   consider the next part of the
                                            expression.
```

The scanning of the line now continues. The present argument may be followed by a '(', a binary operator or, if the end of the expression has been reached, then e.g. a carriage return character or a colon, a separator or a 'THEN'.

```
2712    S-CONT-2    RST     0018,GET-CHAR   Fetch the present character.
2713    S-CONT-3    CP      +28             Jump forward if it is not a '(',
                    JR      NZ,2723,S-OPERTR which indicates a parenthesised
                                            expression.
```

If the 'last value' is numeric then the parenthesised expression is a true sub-expression and must be evaluated by itself. However if the 'last value' is a string then the parenthesised expression represents an element of an array or a slice of a string. A call to SLICING modifies the parameters of the string as required.

```
                    BIT     6,(FLAGS)       Jump forward if dealing with a
                    JR      NZ,2734,S-LOOP  numeric parenthesised
                                            expression.
                    CALL    2A52,SLICING    Modify the parameters of the
                                            'last value'.
                    RST     0020,NEXT-CHAR  Move on to consider the next
                    JR      2713,S-CONT-3   character.
```

If the present character is indeed a binary operator it will be given an operation code in the range +C3 - +CF hex, and the appropriate priority code.

```
2723  S-OPERTR  LD    B,+00              Original code to BC to index
                LD    C,A                into table of operators.
                LD    HL,+2795           The pointer to the table.
                CALL  16DC,INDEXER       Index into the table.
                JR    NC,2734,SLOOP      Jump forward if no operation
                                         found.
                LD    C,(HL)             Get required code from the
                                         table.
                LD    HL,+26ED           The pointer to the priority
                                         table: i.e. 26ED +C3 gives 27B0
                                         as the first address.
                ADD   HL,BC              Index into the table.
                LD    B,(HL)             Fetch the appropriate priority.
```

The main loop of this subroutine is now entered. At this stage there are:

I. A 'last value' on the calculator stack.
II. The starting priority market on the machine stack below a hierarchy, of unknown size, of function and binary operation codes. This hierarchy may be null.
III. The BC register pair holding the 'present' operation and priority, which if the end of an expression has been reached will be priority zero.

Initially the 'last' operation and priority are taken off the machine stack and compared against the 'present' operation and priority.

If the 'present' priority is higher than the 'last' priority then an exit is made from the loop as the 'present' priority is considered to bind tighter than the 'last' priority.

However, if the present priority is less binding, then the operation specified as the 'last' operation is performed. The 'present' operation and priority go back on the machine stack to be carried round the loop again. In this manner the hierarchy of functions and binary operations that have been queued are dealt with in the correct order.

```
2734  S-LOOP    POP   DE                 Get the 'last' operation and
                                         priority.
                LD    A,D                The priority goes to the A
                                         register.
                CP    B                  Compare 'last' against 'present'.
                JR    C,2773,S-TIGHTER   Exit to wait for the argument.
                AND   A                  Are both priorities zero?
                JP    Z,0018,GET-CHAR    Exit via GET-CHAR thereby
                                         making 'last value' the required
                                         result.
```

Before the 'last' operation is performed, the 'USR' function is separated into 'USR number' and 'USR string' according as bit 6 of FLAGS was set or reset when the argument of the function was stacked as the 'last value'.

```
                PUSH  BC                 Stack the 'present' values.
                LO    HL,+5C3B           This is FLAGS.
                LD    A,E                The 'last' operation is compared
                CP    +ED                with the code for USR, which
                JR    NZ,274C,S-STK-LST  will give 'USR number' unless
                                         modified; jump if not 'USR'.
                BIT   6,(HL)             Test bit 6 of FLAGS.
                JR    NZ,274C,S-STK-LST  Jump if it is set ('USR number').
                LD    E,+99              Modify the 'last' operation
                                         code: 'offset' 19, +80 for string
                                         input and numerical result
                                         ('USR string').
274C  S-STK-LST PUSH  DE                 Stack the 'last' values briefly.
                CALL  2530,SYNTAX-Z      Do not perform the actual
                JR    Z,275B,S-SYNTEST   operation if syntax is being
                                         checked.
```

```
                LD      A,E             The 'last' operation code.
                AND     +3F             Strip off bits 6 and 7 to convert
                LD      B,A             the operation code to a
                                        calculator offset.
                RST     0028,FP-CALC    Now use the calculator.
                DEFB    +3B,fp-calc-2   Perform the actual operation
                DEFB    +38,end-calc    It has been done.
                JR      2764,S-RUNTEST  Jump forward.
```

An important part of syntax checking involves the testing of the operation to ensure that the nature of the 'last value' is of the correct type for the operation under consideration.

```
275B  S-SYNTEST LD      A,E             Get the 'last' operation code.
                XOR     (FLAGS)         This tests the nature of the 'last
                AND     +40             value' against the requirement
                                        of the operation. They are to be
                                        the same for correct syntax.
2761  S-RPORT-C JP      NZ,1C8A,REPORT-C Jump if syntax fails.
```

Before jumping back to go round the loop again the nature of the 'last value' must be recorded in FLAGS.

```
2764  S-RUNTEST POP     DE              Get the 'last' operation code.
                LD      HL,+5C3B        This is FLAGS.
                SET     6,(HL)          Assume result to be numeric.
                BIT     7,E             Jump forward if the nature of
                JR      NZ,2770,S-LOOPEND 'last value' is numeric.
                RES     6,(HL)          It is string.
2770  S-LOOPEND POP     BC              Get the 'present' values into BC:
                JR      2734,S-LOOP     Jump back.
```

Whenever the 'present' operation binds tighter, the 'last' and the 'present' values go back on the machine stack. However if the 'present' operation requires a string as its operand then the operation code is modified to indicate this requirement.

```
2773  S-TIGHTER PUSH    DE              The 'last' values go on the stack.
                LD      A,C             Get the 'present' operation
                                        code.
                BIT     6,(FLAGS)       Do not modify the operation
                JR      NZ,2790,S-NEXT  code if dealing with a numeric
                                        operand.
                AND     +3F             Clear bits 6 and 7.
                ADD     A,+08           Increase the code by +08 hex.
                LD      C,A             Return the code to the C
                                        register.
                CP      +10             Is the operation 'AND'?
                JR      NZ,2788,S-NOT-AND Jump if it is not so.
                SET     6,C             'AND' requires a numeric
                                        operand.
                JR      2790,S-NEXT     Jump forward.
2788  S-NOT-AND JR      C,2761,S-RPORT-C The operations -,*,/,^ and OR
                                        are not possible between strings.
                CP      +17             Is the operation a '+'?
                JR      Z,2790,S-NEXT   Jump if it is so.
                SET     7,C             The other operations yield a
                                        numeric result.
2790  S-NEXT    PUSH    BC              The 'present' values go on the
                                        machine stack.
                RST     0020,NEXT-CHAR  Consider the next character.
                JP      24FF,S-LOOP-1   Go around the loop again.
```

THE TABLE OF OPERATORS

location	code	operator code	operator	location	code	operator code	operator
2795	2B	CF	+	27A3	3C	CD	<
2797	2D	C3	-	27A5	C7	C9	<=
2799	2A	C4	*	27A7	C8	CA	>=
279B	2F	C5	/	27A9	C9	CB	<>
279D	5E	C6	^	27AB	C5	C7	OR
279F	3D	CE	=	27AD	C6	C8	AND
27A1	3E	CC	>	27AF	00	End marker	

THE TABLE OF PRIORITIES (precedence table)

location	priority	operator	location	priority	operator
27B0	06	-	27B7	05	>=
27B1	08	*	27B8	05	<>
27B2	08	/	27B9	05	>
27B3	0A	^	27BA	05	<
27B4	02	OR	27BB	05	=
27B5	03	AND	27BC	06	+
27B6	05	<=			

THE 'SCANNING FUNCTION' SUBROUTINE

This subroutine is called by the 'scanning FN routine' to evaluate a user defined function which occurs in a BASIC line. The subroutine can be considered in four stages:

I. The syntax of the FN statement is checked during syntax checking.
II. During line execution, a search is made of the program area for a DEF FN statement, and the names of the functions are compared, until a match is found - or an error is reported.
III. The arguments of the FN are evaluated by calls to SCANNING.
IV. The function itself is evaluated by calling SCANNING, which in turn calls LOOK-VARS and so the 'STACK FUNCTION ARGUMENT' subroutine.

```
27BD    S-FN-SBRN   CALL    2530,SYNTAX-Z       Unless syntax is being checked,
                    JR      NZ,27F7,SF-RUN      a jump is made to SF-RUN.
                    RST     0020,NEXT-CHAR      Get the first character of the
                                                name.
                    CALL    2C8D,ALPHA          If it is not alphabetic, then
                    JP      NC,1C8A,REPORT-C    report the error.
                    RST     0020,NEXT-CHAR      Get the next character.
                    CP      +24                 Is it a '$'?
                    PUSH    AF                  Save the zero flag on the stack.
                    JR      NZ,27D0,SF-BRKT-1   Jump if it was not a '$'.
                    RST     0020,NEXT-CHAR      But get the next character if it
                                                was.
27D0    SF-BRKT-1   CP      +28                 If the character is not a '(', then
                    JR      NZ,27E6,SF-RPRT-C   report the error.
                    RST     0020,NEXT-CHAR      Get the next character.
                    CP      +29                 Is it a ')'?
                    JR      Z,27E9,SF-FLAG-6    Jump if it is; there are no argu-
                                                ments.
27D9    SF-ARGMTS   CALL    24FB,SCANNING       Within the loop, call SCANNING
                                                to check the syntax of each
                                                argument and to insert floating-
                                                point numbers.
                    RST     0018,GET-CHAR       Get the character which follows
                    CP      +2C                 the argument; if it is not a ','
                    JR      NZ,27E4,SF-BRKT-2   then jump - no more arguments.
                    RST     0020,NEXT-CHAR      Get the first character in the
                                                next argument.
```

```
                    JR      27D9,SF-ARGMTS      Loop back to consider this
                                                argument.
27E4    SF-BRKT-2   CP      +29                 Is the current character a ')'?
27E6    SF-RPRT-C   JP      NZ,1C8A,REPORT-C    Report the error if it is not.
27E9    SF-FLAG-6   RST     0020,NEXT-CHAR      Point to the next character in
                                                the BASIC line.
                    LD      HL.+5C3B            This is FLAGS; assume a string-
                    RES     6,(HL)              valued function and reset bit 6
                                                of FLAGS.
                    POP     AF                  Restore the zero flag, jump if
                    JR      Z,27F4,SF-SYN-EN    the FN is indeed string valued.
                    SET     6,(HL)              Otherwise, set bit 6 of FLAGS
27F4    SF-SYN-EN   JP      2712,S-CONT-2       Jump back to continue scanning
                                                the line.
```

ii. During line execution, a search must first be made for a DEF FN statement.

```
27F7    SF-RUN      RST     0020,NEXT-CHAR      Get the first character of the
                                                name.
                    AND     +DF                 Reset bit 5 for upper case.
                    LD      B,A                 Copy the name to B.
                    RST     0020,NEXT-CHAR      Get the next character.
                    SUB     +24                 Subtract 24 hex, the code for '$'.
                    LD      C,A                 Copy the result to C (zero for a
                                                string, non-zero for a numerical
                                                function).
                    JR      NZ,2802,SF-ARGMT1   Jump if non-zero: numerical
                                                function.
                    RST     0020,NEXT-CHAR      Get the next character, the '('.
2802    SF-ARGMT1   RST     0020,NEXT-CHAR      Get 1st character of 1st argu-
                                                ment.
                    PUSH    HL                  Save the pointer to it on the
                                                stack.
                    LD      HL,(PROG)           Point to the start of the
                                                program.
                    DEC     HL                  Go back one location.
2808    SF-FND-DF   LD      DE,+00CE            The search will be for 'DEF FN'.
                    PUSH    BC                  Save the name and 'string
                                                status'.
                    CALL    1D86,LOOK-PROG      Search the program now.
                    POP     BC                  Restore the name and status.
                    JR      NC,2814,SF-CP-DEF   Jump if a DEF FN statement
                                                found.
```

REPORT P - FN without DEF.

```
2812    REPORT-P    RST     0008,ERROR-1        Call the error handling
                    DEFB    +18                 routine.
```

When a DEF FN statement is found, the name and status of the two functions are compared: if they do not match, the search is resumed.

```
2814    SF-CP-DEF   PUSH    HL                  Save the pointer to the DEF FN
                                                character in case the search has
                                                to be resumed.
                    CALL    28AB,FN-SKPOVR      Get the name of the DEF FN
                                                function.
                    AND     +DF                 Reset bit 5 for upper case.
                    CP      B                   Does it match the FN name?
                    JR      NZ,2825,SF-NOT-FD   Jump if it does not match.
                    CALL    28AB,FN-SKPOVR      Get the next character in the
                                                DEF FN.
                    SUB     +24                 Subtract 24 hex, the code for
                                                '$'.
                    CP      C                   Compare the status with that of
                                                FN.
```

		JR	Z,2831,SF-VALUES	Jump if complete match now found.
2825	SF-NOT-FD	POP	HL	Restore the pointer to the 'DEF FN'.
		DEC	HL	Step back one location.
		LD	DE,+0200	Use the search routine to find
		PUSH	BC	the end of the DEF FN state-
		CALL	198B,EACH-STMT	ment, preparing for the next
		POP	BC	search; save the name and status meanwhile.
		JR	2808,SF-FND-DF	Jump back for a further search.

ii. The correct DEF FN statement has now been found. The arguments of the FN statement will be evaluated by repeated calls of SCANNING, and their 5 byte values (or parameters, for strings) will be inserted into the DEF FN statement in the spaces made there at syntax checking. HL will be used to point along the DEF FN statement (calling FN-SKPOVR as needed) while CH-ADD points along the FN statement (calling RST 0020, NEXT-CHAR, as needed).

2831	SF-VALUES	AND	A	If HL is now pointing to a '$',
		CALL	Z,28AB,FN-SKPOVR	move on to the '('.
		POP	DE	Discard the pointer to 'DEF FN'.
		POP	DE	Get the pointer to the first
		LD	(CH-ADD),DE	argument of FN, and copy it to CH-ADD.
		CALL	28AB,FN-SKPOVR	Move past the '(' now.
		PUSH	HL	Save this pointer on the stack.
		CP	+29	Is it pointing to a ')'?
		JR	Z,2885,SF-R-BR-2	If so, jump: FN has no argu- ments.
2843	SF-ARG-LP	INC	HL	Point to the next code.
		LD	A,(HL)	Put the code into A.
		CP	+0E	Is it the 'number marker' code, 0E hex?
		LD	D,+40	Set bit 6 of D for a numerical argument.
		JR	Z,2852,SF-ARG-VL	Jump on zero: numerical argument.
		DEC	HL	Now ensure that HL is pointing to the '$' character (not e.g. to a
		CALL	28AB,FN-SKPOVR	control code).
		INC	HL	HL now points to the 'number marker'.
		LD	D,+00	Bit 6 of D is reset: string argument.
2852	SF-ARG-VL	INC	HL	Point to the 1st of the 5 bytes in DEF FN.
		PUSH	HL	Save this pointer on the stack.
		PUSH	DE	Save the 'string status' of the argument.
		CALL	24FB,SCANNING	Now evaluate the argument.
		POP	AF	Get the no./string flag into A.
		XOR	(FLAGS)	Test bit 6 of it against the result
		AND	+40	of SCANNING.
		JR	NZ,288B,REPORT-Q	Give report Q if they did not match.
		POP	HL	Get the pointer to the first of
		EX	DE,HL	the 5 spaces in DEF FN into DE.
		LD	HL,(STKEND)	Point HL at STKEND.
		LD	BC,+0005	BC will count 5 bytes to be moved.
		SBC	HL,BC	First, decrease STKEND by 5,

```
                    LD      (STKEND),HL     so deleting the 'last value' from
                                            the stack.
                    LDIR                    Copy the 5 bytes into the spaces
                                            in DEF FN.
                    EX      DE,HL           Point HL at the next code.
                    DEC     HL              Ensure that HL points to the
                    CALL    28AB,FN-SKPOVR  character after the 5 bytes.
                    CP      +29             Is it a ')'?
                    JR      Z,2885,SF-R-BR-2 Jump if it is: no more
                                            arguments in the DEF FN
                                            statement.
                    PUSH    HL              It is a ',': save the pointer to it.
                    RST     0018,GET-CHAR   Get the character after the last
                                            argument that was evaluated
                                            from FN.
                    CP      +2C             If it is not a ',' jump: mis-
                    JR      NZ,288B,REPORT-Q matched arguments of FN and
                                            DEF FN.
                    RST     0020,NEXT-CHAR  Point CH-ADD to the next
                                            argument of FN.
                    POP     HL              Point HL to the ',' in DEF FN
                                            again.
                    CALL    28AB,FN-SKPOVR  Move HL on to the next argu-
                                            ment in DEF FN.
                    JR      2843,SF-ARG-LP  Jump back to consider this
                                            argument.
2885    SF-R-BR-2   PUSH    HL              Save the pointer to the ')' in
                                            DEF FN.
                    RST     0018,GET-CHAR   Get the character after the last
                                            argument in FN.
                    CP      +29             Is it a ')'?
                    JR      Z,288D,SF-VALUE If so, jump to evaluate the
                                            function; but if not, give report
                                            Q.

REPORT Q - Parameter error.
288B    REPORT-Q    RST     0008,ERROR-1    Call the error handling
                    DEFB    +19             routine.
```

iv. Finally, the function itself is evaluated by calling SCANNING, after first setting DEFADD to hold the address of the arguments as they occur in the DEF FN statement. This ensures that LOOK-VARS, when called by SCANNING, will first search these arguments for the required values, before making a search of the variables area.

```
288D    SF-VALUE    POP     DE              Restore pointer to ')' in DEF
                                            FN.
                    EX      DE,HL           Get this pointer into HL.
                    LD      (CH-ADD),HL     Insert it into CH-ADD.
                    LD      HL,(DEFADD)     Get the old value of DEFADD.
                    EX      (SP),HL         Stack it, and get the start
                    LD      (DEFADD),HL     address of the arguments area of
                                            DEF FN into DEFADD.
                    PUSH    DE              Save address of ')' in FN.
                    RST     0020,NEXT-CHAR  Move CH-ADD on past ')' and
                    RST     0020,NEXT-CHAR  '=' to the start of the expression
                                            for the function in DEF FN.
                    CALL    24FB,SCANNING   Now evaluate the function.
                    POP     HL              Restore the address of ')' in
                                            FN.
                    LD      (CH-ADD),HL     Store it in CH-ADD.
                    POP     HL              Restore original value of
                                            DEFADD.
                    LD      (DEFADD),HL     Put it back into DEFADD.
```

		RST	0020,NEXT-CHAR	Get the next character in the BASIC line.
		JP	2712,S-CONT-2	Jump back to continue scanning.

THE 'FUNCTION SKIPOVER' SUBROUTINE

This subroutine is used by FN and by STK-F-ARG to move HL along the DEF FN statement while leaving CM-ADD undisturbed, as it points along the FN statement.

28AB	FN-SKPOVR	INC	HL	Point to the next code in the statement.
		LD	A,(HL)	Copy the code to A.
		CP	+21	Jump back to skip over it if it is
		JR	C,28AB,FN-SKPOVR	a control code or a space.
		RET		Finished.

THE 'LOOK-VARS' SUBROUTINE

This subroutine is called whenever a search of the variables area or of the arguments of a DEF FN statement is required. The subroutine is entered with the system variable CH-ADD pointing to the first letter of the name of the variable whose location is being sought. The name will be in the program area or the work space. The subroutine initially builds up a discriminator byte, in the C register, that is based on the first letter of the variable's name. Bits 5 & 6 of this byte indicate the type of the variable that is being handled.

The B register is used as a bit register to hold flags.

28B2	LOOK-VARS	SET	6,(FLAGS)	Presume a numeric variable.
		RST	0018,GET-CHAR	Get the first character into A.
		CALL	2C8D,ALPHA	Is it alphabetic?
		JP	NC,1C8A,REPORT-C	Give an error report if it is not so.
		PUSH	HL	Save the pointer to the first letter.
		AND	+1F	Transfer bits 0 to 4 of the letter
		LD	C,A	to the C register; bits 5 & 7 are always reset.
		RST	0020,NEXT-CHAR	Get the 2nd character into A.
		PUSH	HL	Save this pointer also.
		CP	+28	is the 2nd character a '('?
		JR	Z,28EF,V-RUN/SYN	Separate arrays of numbers.
		SET	6,C	Now set bit 6.
		CP	+24	Is the 2nd character a '$'?
		JR	Z,28DE,V-STR-VAR	Separate all the strings.
		SET	5,C	Now set bit 5.
		CALL	2C88,ALPHANUM	If the variable's name has only
		JR	NC,28E3,V-TEST-FN	one character then jump forward.

Now find the end character of a name that has more than one character.

28D4	V-CHAR	CALL	2C88,ALPHANUM	Is the character alphanumeric?
		JR	NC,28EF,V-RUN/SYN	Jump out of the loop when the end of the name is found.
		RES	6,C	Mark the discriminator byte.
		RST	0020,NEXT-CHAR	Get the next character.
		JR	28D4,V-CHAR	Go back to test it.

Simple strings and arrays of strings require that bit 6 of FLAGS is reset.

28DE	V-STR-VAR	RST	0020,NEXT-CHAR	Step CH-ADD past the '$'.
		RES	6,(FLAGS)	Reset the bit 6 to indicate a string.

If DEFADD-hi is non-zero, indicating that a 'function' (a 'FN') is being evaluated, and if in 'run-time', a search will be made of the arguments in the DEF FN statement.

28E3	V-TEST-FN	LD	A,(DEFADD-hi)	Is DEFADD-hi zero?

```
                AND     A
                JR      Z,28EF,V-RUN/SYN        If so, jump forward.
                CALL    2530,SYNTAX-Z           In 'run-time'?
                JP      NZ,2951,STK-F-ARG       If so, jump forward to search
                                                the DEF FN statement.
```

Otherwise (or if the variable was not found in the DEF FN statement) a search of variables area will be made, unless syntax is being checked.

```
28EF  V-RUN/SYN LD      B,C             Copy the discriminator bytes to
                                        the B register.
                CALL    2530,SYNTAX-Z   Jump forward if in
                JR      NZ,28FD,V-RUN   'run-time'.
                LD      A,C             Move the discriminator to A.
                AND     +E0             Drop the character code part.
                SET     7,A             Indicate syntax by setting bit 7.
                LD      C,A             Restore the discriminator.
                JR      2934,V-SYNTAX   Jump forward to continue.
```

A BASIC line is being executed so make a search of the variables area.

```
28FD  V-RUN     LD      HL,(VARS)       Pick up the VARS pointer.
```

Now enter a loop to consider the names of the existing variables.

```
2900  V-EACH    LD      A,(HL)          The 1st. letter of each
                                        existing variable.
                AND     +7F             Match on bits 0 to 6.
                JR      Z,2932,V-80-BYTE Jump when the '80-byte' is
                                        reached.
                CP      C               The actual comparison.
                JR      NZ,292A,V-NEXT  Jump forward if the 1st
                                        characters do not match.
                RLA                     Rotate A leftwards and then
                ADD     A,A             double it to test bits 5 & 6.
                JP      P,293F,V-FOUND-2 Strings and array variables.
                JR      C,293F,V-FOUND-2 Simple numeric and FOR-NEXT
                                        variables.
```

Long names are required to be matched fully.

```
                POP     DE              Take a copy of the pointer
                PUSH    DE              to the 2nd. character.
                PUSH    HL              Save the 1st letter pointer.
2912  V-MATCHES INC     HL              Consider the next character.
2913  V-SPACES  LD      A,(DE)          Fetch each character in turn.
                INC     DE              Point to the next character.
                CP      +20             Is the character a 'space'?
                JR      Z,2913,V-SPACES Ignore the spaces.
                OR      +20             Set bit 5 so as to match
                                        lower and upper case letters.
                CP      (HL)            Make the comparison.
                JR      Z,2912,V-MATCHES Back for another character if
                                        it does match.
                OR      +80             Will it match with bit 7 set?
                CP      (HL)            Try it.
                JR      NZ,2929,V-GET-PTR Jump forward if the 'last
                                        characters' do not match.
                LD      A,(DE)          Check that the end of the
                CALL    2C88,ALPHANUM   name has been reached before
                JR      NC,293E,V-FOUND-1 jumping forward.
```

In all cases where the names fail to match the HL register pair has to be made to point to the next variable in the variables area.

```
2929  V-GET-PTR POP     HL              Fetch the pointer.
292A  V-NEXT    PUSH    BC              Save B & C briefly.
                CALL    19B8,NEXT-ONE   DE is made to point to the
                                        next variable.
```

```
                EX      DE,HL           Switch the two pointers.
                POP     BC              Get B & C back.
                JR      2900,V-EACH     Go around the loop again.
```

Come here if no entry was found with the correct name.

```
2932  V-80-BYTE SET     7,B             Signal 'variable not found'.
```

Come here if checking syntax.

```
2934  V-SYNTAX  POP     DE              Drop the pointer to the
                                        2nd. character.
                RST     0018,GET-CHAR   Fetch the present character.
                CP      +28             Is it a '('?
                JR      Z,2943,V-PASS   Jump forward.
                SET     5,B             Indicate not dealing with an
                JR      294B,V-END      array and jump forward.
```

Come here when an entry with the correct name was found.

```
293E  V-FOUND-1 POP     DE              Drop the saved variable pointer.
293F  V-FOUND-2 POP     DE              Drop the 2nd character pointer.
                POP     DE              Drop the first letter pointer.
                PUSH    HL              Save the 'last' letter pointer.
                RST     0018,GET-CHAR   Fetch the current character.
```

If the matching variable name has more than a single letter then the other characters must be passed-over.

Note: This appears to have been done already at V-CHAR.

```
2943  V-PASS    CALL    2C88,ALPHANUM   Is it alphanumeric?
                JR      NC,294B,V-END   Jump when the end of the name
                                        has been found.
                RST     0020,NEXT-CHAR  Fetch the next character.
                JR      2943,V-PASS     Go back and test it.
```

The exit-parameters are now set.

```
294B  V-END     POP     HL              HL holds the pointer to the
                                        letter of a short name or the
                                        'last' character of a long name.
                RL      B               Rotate the whole register.
                BIT     6,B             Specify the state of bit 6.
                RET                     Finished.
```

The exit-parameters for the subroutine can be summarised as follows: The system variable CH-ADD points to the first location after the name of the variable as it occurs in the BASIC line.

When 'variable not found':

I. The carry flag is set.
II. The zero flag is set only when the search was for an array variable.
III. The HL register pair points to the first letter of the name of the variable as it occurs in the BASIC line.

When 'variable found':

I. The carry flag is reset.
II. The zero flag is set for both simple string variables and all array variables.
III. The HL register pair points to the letter of a 'short' name, or the last character of a 'long' name, of the existing entry that was found in the variables area.

In all cases bits 5 & 6 of the C register indicate the type of variable being handled. Bit 7 is the complement of the SYNTAX/RUN flag. But only when the subroutine is used in 'runtime' will bits 0 to 4 hold the code of the variable's letter.

In syntax time the return is always made with the carry flag reset. The zero flag is set for arrays and reset for all other variables, except that a simple string name incorrectly followed by a '$' sets the zero flag and, in the case of SAVE "name" DATA a$(), passes syntax as well.

THE 'STACK FUNCTION ARGUMENT' SUBROUTINE

This subroutine is called by LOOK-VARS when DEFADD-hi in non-zero, to make a search of the arguments area of a DEF FN statement, before searching in the variables area. If the variable is found in the DEF FN statement, then the parameters of a string variable are stacked and a signal is given that there is no need to call STK/VAR. But it is left to SCANNING to stack the value of a numerical variable at 26DA in the usual way.

2951	STK-F-ARG	LD	HL,(DEFADD)	Point to the 1st character in the
		LD	A,(HL)	arguments area and put it into A.
		CP	+29	Is it a ')'?
		JP	Z,28EF,V-RUN/SYN	Jump to search the variables area.
295A	SFA-LOOP	LD	A,(HL)	Get the next argument in the loop.
		OR	+60	Set bits 5 & 6, assuming a
		LD	B,A	simple numeric variable; copy it to B.
		INC	HL	Point to the next code.
		LD	A,(HL)	Put it into the A register.
		CP	+0E	Is it the 'number marker' code 0E hex?
		JR	Z,296B,SFA-CP-VR	Jump if so: numeric variable.
		DEC	HL	Ensure that HL points to the
		CALL	28AB,FN-SKPOVR	character, not to a space or control code.
		INC	HL	HL now points to the 'number marker'.
		RES	5,B	Reset bit 5 of B: string variable.
296B	SFA-CP-VR	LD	A,B	Get the variable name into A.
		CP	C	Is it the one we are looking for?
		JR	Z,2981,SFA-MATCH	Jump if it matches.
		INC	HL	Now pass over the 5 bytes of
		INC	HL	the floating-point number or
		INC	HL	string parameters to get to the
		INC	HL	next argument.
		INC	HL	
		CALL	28AB,FN-SKPOVR	Pass on to the next character.
		CP	+29	Is it a ')'?
		JP	Z,28EF,V-RUN/SYN	If so, jump to search the variables area.
		CALL	28AB,FN-SKPOVR	Point to the next argument.
		JR	295A,SFA-LOOP	Jump back to consider it.

A match has been found. The parameters of a string variable are stacked, avoiding the need to call the STK-VAR subroutine.

2981	SFA-MATCH	BIT	5,C	Test for a numeric variable.
		JR	NZ,2991,SFA-END	Jump if the variable is numeric; SCANNING will stack it.
		INC	HL	Point to the first of the 5 bytes to be stacked.
		LD	DE,(STKEND)	Point DE to STKEND.
		CALL	33C0,MOVE-FP	Stack the 5 bytes.
		EX	DE,HL	Point HL to the new position
		LD	(STKEND),HL	of STKEND, and reset the system variable.
2991	SFA-END	POP	DE	Discard the LOOK-VARS
		POP	DE	pointers (2nd & 1st character pointers).
		XOR	A	Return from the search with
		INC	A	both the carry and zero flags reset - signalling that a call STK-VAR is not required.
		RET		Finished.

THE 'STK-VAR' SUBROUTINE

This subroutine is usually used either to find the parameters that define an existing string entry in the variables area or to return in the HL register pair the base address of a particular element or an array of numbers. When called from DIM the subroutine only checks the syntax of the BASIC statement.

Note that the parameters that define a string may be altered by calling SLICING if this should be specified.

Initially the A and the B registers are cleared and bit 7 of the C register is tested to determine whether syntax is being checked.

```
2996    STK-VAR     XOR     A                   Clear the array flag.
                    LD      B,A                 Clear the B register for later.
                    BIT     7,C                 Jump forward if syntax is
                    JR      NZ,29E7,SV-COUNT    being checked.
```

Next, simple strings are separated from array variables.

```
                    BIT     7,(HL)              Jump forward if dealing with
                    JR      NZ,29AE,SV-ARRAYS   an array variable.
```

The parameters for a simple string are readily found.

```
                    INC     A                   Signal 'a simple string'.
29A1    SV-SIMPLE$  INC     HL                  Move along the entry.
                    LD      C,(HL)              Pick up the low length counter.
                    INC     HL                  Advance the pointer.
                    LD      B,(HL)              Pick up the high length
                                                pointer.
                    INC     HL                  Advance the pointer.
                    EX      DE,HL               Transfer the pointer to the
                                                actual string.
                    CALL    2AB2,STK-STORE      Pass these parameters to the
                                                calculator stack.
                    RST     0018,GET-CHAR       Fetch the present character
                                                and jump forward to see if a
                    JP      2A49,SV-SLICE?      'slice' is required.
```

The base address of an element in an array is now found. Initially the 'number of dimensions' is collected.

```
29AE    SV-ARRAYS   INC     HL                  Step past the length bytes.
                    INC     HL
                    INC     HL
                    LD      B,(HL)              Collect the 'number of
                                                dimensions'.
                    BIT     6,C                 Jump forward if handling an
                    JR      Z,29C0,SV-PTR       array of numbers.
```

If an array of strings has its 'number of dimensions' equal to '1' then such an array can be handled as a simple string.

```
                    DEC     B                   Decrease the 'number of
                    JR      Z,29A1,SV-SIMPLE$   dimensions' and jump if the
                                                number is now zero.
```

Next a check is made to ensure that in the BASIC line the variable is followed by a subscript.

```
                    EX      DE,HL               Save the pointer in DE.
                    RST     0018,GET-CHAR       Get the present character.
                    CP      +28                 Is it a '('?
                    JR      NZ,2A20,REPORT-3    Report the error if it is not so.
                    EX      DE,HL               Restore the pointer.
```

For both numeric arrays and arrays of strings the variable pointer is transferred to the DE register pair before the subscript is evaluated.

```
29C0    SV-PTR      EX      DE,HL               Pass the pointer to DE.
                    JR      29E7,SV-COUNT       Jump forward.
```

The following loop is used to find the parameters of a specified element within an array. The loop is entered at the mid-point - SV-COUNT -, where the element count is set to zero.
The loop is accessed 'B' times, this being, for a numeric array, equal to the number of dimensions that are being used, but for an array of strings 'B' is one less than the number of dimensions in use as the last subscript Is used to specify a 'slice' of the string.

29C3	SV-COMMA	PUSH	HL	Save the counter.
		RST	0018,GET-CHAR	Get the present character.
		POP	HL	Restore the counter.
		CP	+2C	Is the present character a ','?
		JR	Z,29EA,SV-LOOP	Jump forward to consider another subscript.
		BIT	7,C	If a line is being executed
		JR	Z,2A20,REPORT-3	then there is an error.
		BIT	6,C	Jump forward if dealing with
		JR	NZ,29D8,SV-CLOSE	an array of strings.
		CP	+29	Is the present character a ')'?
		JR	NZ,2A12,SV-RPT-C	Report an error if not so.
		RST	0020,NEXT-CHAR	Advance CH-ADD.
		RET		Return as the syntax is correct.

For an array of strings the present subscript may represent a 'slice', or the subscript for a 'slice' may yet be present in the BASIC line.

29D8	SV-CLOSE	CP	+29	Is the present character a ')'?
		JR	Z,2A48,SV-DIM	Jump forward and check whether there is another sub-script.
		CP	+CC	Is the present character a 'TO'?
		JR	NZ,2A12,SV-RPT-C	It must not be otherwise.
29E0	SV-CH-ADD	RST	0018,GET-CHAR	Get the present character.
		DEC	HL	Point to the preceding
		LD	(CH-ADD),HL	character and set CH-ADD.
		JR	2A45,SV-SLICE	Evaluate the 'slice'.

Enter the loop here.

29E7	SV-COUNT	LD	HL,+0000	Set the counter to zero.
29EA	SV-LOOP	PUSH	HL	Save the counter briefly.
		RST	0020,NEXT-CHAR	Advance CH-ADD.
		POP	HL	Restore the counter.
		LD	A,C	Fetch the discriminator byte.
		CP	+C0	Jump unless checking the
		JR	NZ,29FB,SV-MULT	syntax for an array of strings.
		RST	0018,GET-CHAR	Get the present character.
		CP	+29	Is it a ')'?
		JR	Z,2A48,SV-DIM	Jump forward as finished counting elements.
		CP	+CC	Is to 'TO'?
		JR	Z,29E0,SV-CH-ADD	Jump back if dealing with a 'slice'.
29FB	SV-MULT	PUSH	BC	Save the dimension-number counter and the discriminator byte.
		PUSH	HL	Save the element-counter.
		CALL	2AEE,DE,(DE+1)	Get a dimension-size Into DE.
		EX	(SP),HL	The counter moves to HL and the variable pointer is stacked.
		EX	DE,HL	The counter moves to DE and the dimension-size to HL.
		CALL	2ACC,INT-EXP1	Evaluate the next subscript.
		JR	C,2A20,REPORT-3	Give an error if out of range.
		DEC	BC	The result of the evaluation is decremented as the counter is to

```
                                                  count the elements occurring
                                                  before the specified element.
            CALL    2AF4,GET-HL*DE                Multiply the counter by the
                                                  dimension-size.
            ADD     HL,BC                         Add the result of 'INT-EXP1'
                                                  to the present counter.
            POP     DE                            Fetch the variable pointer.
            POP     BC                            Fetch the dimension-number
                                                  and the discriminator byte.
            DJNZ    29C3,SV-COMMA                 Keep going round the loop
                                                  until 'B' equals zero.
```

The SYNTAX/RUN flag is checked before arrays of strings are separated from arrays of numbers.

```
            BIT     7,C                           Report an error if checking
2A12  SV-RPT-C  JR  NZ,2A7A,SL-RPT-C              syntax at this point.
            PUSH    HL                            Save the counter.
            BIT     6,C                           Jump forward if handling
            JR      NZ,2A2C,SV-ELEM$              an array of strings.
```

When dealing with an array of numbers the present character must be a ')'.

```
            LD      B,D                           Transfer the variable pointer
            LD      C,E                           to the BC register pair.
            RST     0018,GET-CHAR                 Fetch the present character.
            CP      +29                           Is it a ')'?
            JR      Z,2A22,SV-NUMBER              Jump past the error report
                                                  unless it is needed.
```

Report 3 - Subscript out of range

```
2A20  REPORT-3  RST     0008,ERROR-1              Call the error handling
            DEFB    +02                           routine.
```

The address of the location before the actual floating-point form can now be calculated.

```
2A22  SV-NUMBER RST     0020,NEXT-CHAR            Advance CH-ADD.
            POP     HL                            Fetch the counter.
            LD      DE,+0005                      There are 5 bytes to each
                                                  element in an array of numbers.
            CALL    2AF4,GET-HL*DE                Compute the total number of
                                                  bytes before the required
                                                  element.
            ADD     HL,BC                         Make HL point to the location
                                                  before the required element.
            RET                                   Return with this address.
```

When dealing with an array of strings the length of an element is given by the last 'dimension-size'. The appropriate parameters are calculated and then passed to the calculator stack.

```
2A2C  SV-ELEM$  CALL    2AEE,DE,(DE+1)            Fetch the last dimension-size.
            EX      (SP),HL                       The variable printer goes on the
                                                  stack and the counter to HL.
            CALL    2AF4,GET-HL*DE                Multiply 'counter' by
                                                  'dimension-size'.
            POP     BC                            Fetch the variable pointer.
            ADD     HL,BC                         This gives HL pointing to the
                                                  location before the string.
            INC     HL                            So point to the actual 'start'.
            LD      B,D                           Transfer the last dimension-
            LD      C,E                           size to BC to form the 'length'.
            EX      DE,HL                         Move the 'start' to DE.
            CALL    2AB1,STK-ST-0                 Pass these parameters to the
                                                  calculator stack. Note: The first
                                                  parameter is zero indicating a
                                                  string from an 'array of strings'
```

```
                                                  and hence the existing entry is
                                                  not to be reclaimed.
```

There are three possible forms of the last subscript. The first is illustrated by - A$(2,4 TO 8) -, the second by - A$(2)(4 TO 8) - and the third by - A$(2) - which is the default form and indicates that the whole string is required.

```
                    RST     0018,GET-CHAR       Get the present character.
                    CP      +29                 Is it a ')'?
                    JR      Z,2A48,SV-DIM       Jump if it is so.
                    CP      +2C                 Is it a ','?
                    JR      NZ,2A20,REPORT-3    Report the error if not so.
2A45    SV-SLICE    CALL    2A52,SLICING        Use SLICING to modify the
                                                set of parameters.
2A48    SV-DIM      RST     0020,NEXT-CHAR      Fetch the next character.
2A49    SV-SLICE?   CP      +28                 Is It a '('?
                    JR      Z,2A45,SV-SLICE     Jump back if there is a
                                                'slice' to be considered.
```

When finished considering the last subscript a return can be made.

```
                    RES     6,(FLAGS)           Signal - string result.
                    RET                         Return with the parameters of
                                                the required string forming a
                                                'last value' on the calculator
                                                stack.
```

THE 'SLICING' SUBROUTINE

The present string can be sliced using this subroutine. The subroutine is entered with the parameters of the string being present on the top of the calculator stack and in the registers A, B, C, D & E. Initially the SYNTAX/RUN flag is tested and the parameters of the string are fetched only if a line is being executed.

```
2A52    SLICING     CALL    2530,SYNTAX-Z       Check the flag.
                    CALL    NZ,2BF1,STK-FETCH   Take the parameters off the
                                                stack in 'run-time'.
```

The possibility of the 'slice' being '()' has to be considered.

```
                    RST     0020,NEXT-CHAR      Get the next character.
                    CP      +29                 Is it a ')'?
                    JR      Z,2AAD,SL-STORE     Jump forward if it is so.
```

Before proceeding the registers are manipulated as follows:

```
                    PUSH    DE                  The 'start' goes on the
                                                machine stack.
                    XOR     A                   The A register is cleared
                    PUSH    AF                  and saved.
                    PUSH    BC                  The 'length' is saved briefly.
                    LD      DE,+0001            Presume that the 'slice' is to
                                                begin with the first character.
                    RST     0018,GET-CHAR       Get the first character.
                    POP     HL                  Pass the 'length' to HL.
```

The first parameter of the 'slice' is now evaluated.

```
                    CP      +CC                 Is the present character a
                                                'TO'?
                    JR      Z,2A81,SL-SECOND    The first parameter, by default,
                                                will be '1' if the jump is taken.
                    POP     AF                  At this stage A is zero.
                    CALL    2ACD,INT-EXP2       BC is made to hold the first
                                                parameter. A will hold +FF if
                                                there has been an 'out of range'
                                                error.
                    PUSH    AF                  Save the value anyway.
                    LD      D,B                 Transfer the first parameter
                    LD      E,C                 to DE.
                    PUSH    HL                  Save the 'length' briefly.
```

```
                    RST     0018,GET-CHAR       Get the present character.
                    POP     HL                  Restore the 'length'.
                    CP      +CC                 Is the present character a 'TO'?
                    JR      Z,2A81,SL-SECOND    Jump forward to consider the
                                                second parameter if it is so;
                                                CP +29 otherwise show that there is
2A7A    SL-RPT-C    JP      NZ,1C8A,REPORT-C    a closing bracket.
```

At this point a 'slice' of a single character has been identified. e.g. - A$(4).

```
                    LD      H,D                 The last character of the 'slice'
                    LD      L,E                 is also the first character.
                    JR      2A94,SL-DEFINE      Jump forward.
```

The second parameter of a 'slice' is now evaluated.

```
2A81    SL-SECOND   PUSH    HL                  Save the 'length' briefly.
                    RST     0020,NEXT-CHAR      Get the next character.
                    POP     HL                  Restore the 'length'.
                    CP      +29                 Is the present character a
                                                ')'?
                    JR      Z,2A94,SL-DEFINE    Jump if there is not a
                                                second parameter.
                    POP     AF                  If the first parameter was in
                                                range A will hold zero;
                                                otherwise +FF.
                    CALL    2ACD,INT-EXP2       Make BC hold the second
                                                parameter.
                    PUSH    AF                  Save the 'error register'.
                    RST     0018,GET-CHAR       Get the present character.
                    LD      H,B                 Pass the result obtained from
                    LD      L,C                 INT-EXP2 to the HL register
                                                pair.
                    CP      +29                 Check that there is a closing
                    JR      NZ,2A7A,SL-RPT-C    bracket now.
```

The 'new' parameters are now defined.

```
2A94    SL-DEFINE   POP     AF                  Fetch the 'error register'.
                    EX      (SP),HL             The second parameter goes on
                                                the stack and the 'start' goes to
                                                HL.
                    ADD     HL,DE               The first parameter is added
                                                to the 'start'.
                    DEC     HL                  Go back a location to get it
                                                correct.
                    EX      (SP),HL             The 'new start' goes on the
                                                stack and the second parameter
                                                goes to HL.
                    AND     A                   Subtract the first parameters
                    SBC     HL,DE               from the second to find the
                                                length of the 'slice'.
                    LD      BC,+0000            Initialise the 'new length'.
                    JR      C,2AA8,SL-OVER      A negative 'slice' is a 'null
                                                string' rather than an error
                                                condition. (See manual.)
                    INC     HL                  Allow for the inclusive byte.
                    AND     A                   Only now test the 'error
                                                register'.
                    JP      M,2A20,REPORT-3     Jump if either parameter was
                                                out of range for the string.
                    LD      B,H                 Transfer the 'new length'
                    LD      C,L                 to BC.
2AA8    SL-OVER     POP     DE                  Get the 'new start'.
                    RES     6,(FLAGS)           Ensure that a string is still
                                                indicated.
```

```
2AAD    SL-STORE    CALL    2530,SYNTAX-Z    Return at this point if
                    RET     Z                checking syntax; otherwise
                                             continue into the STK-STORE
                                             subroutine.
```

THE 'STK-STORE' SUBROUTINE

This subroutine passes the values held in the A, B, C, D & E registers to the calculator stack. The stack thereby grows in size by 5 bytes with every call to this subroutine.
The subroutine is normally used to transfer the parameters of strings but it is also used by STACK-BC and LOG (2^A) to transfer 'small integers' to the stack.
Note that when storing the parameters of a string the first value stored (coming from the A register) will be a zero if the string comes from an array of strings or is a 'slice' of a string. The value will be '1' for a complete simple string. This 'flag' is used in the 'LET' command routine when the '1' signals that the old copy of the string is to be 'reclaimed'.

```
2AB1    STK-ST-0    XOR     A                Signal - a string from an
                                             array of strings or a 'sliced'
                                             string.
2AB2    STK-STO-$   RES     6,(FLAGS)        Ensure the flag Indicates a
                                             string result.
2AB6    STK-STORE   PUSH    BC               Save B & C briefly.
                    CALL    33A9,TEST-5-SP   Is there room for 5 bytes?
                                             Do not return here unless there
                                             is room available.
                    POP     BC               Restore B & C.
                    LD      HL,(STKEND)      Fetch the address of the first
                                             location above the present
                                             stack.
                    LD      (HL),A           Transfer the first byte.
                    INC     HL               Step on.
                    LD      (HL),E           Transfer the second and
                    INC     HL               third bytes; for a string
                    LD      (HL),D           these will be the 'start'.
                    INC     HL               Step on.
                    LD      (HL),C           Transfer the fourth and
                    INC     HL               fifth bytes; for a string
                    LD      (HL),B           these will be the 'length'.
                    INC     HL               Step on so as to point to the
                                             location above the stack.
                    LD      (STKEND),HL      Save this address In STKEND
                    RET                      and return.
```

THE 'INT-EXP' SUBROUTINE

This subroutine returns the result of evaluating the 'next expression' as an integer value held in the BC register pair. The subroutine also tests this result against a limit-value supplied in the HL register pair. The carry flag becomes set if there is an 'out of range' error. The A register is used as an 'error register' and holds +00 of there is no 'previous error' and +FF if there has been one.

```
2ACC    INT-EXP1    XOR     A                Clear the 'error register'.
2ACD    INT-EXP2    PUSH    DE               Save both the DE & HL
                    PUSH    HL               register pairs throughout.
                    PUSH    AF               Save the 'error register'
                                             briefly.
                    CALL    1C82,EXPT-1NUM   The 'next expression' is
                                             evaluated to give a 'last value'
                                             on the calculator stack.
                    POP     AF               Restore the 'error register'.
                    CALL    2530,SYNTAX-Z    Jump forward if checking
```

```
                JR      Z,2AEB,I-RESTORE    syntax.
                PUSH    AF                  Save the error register again.
                CALL    1E99,FIND-INT2      The 'last value' is
                                            compressed Into BC.
                POP     DE                  Error register to D.
                LD      A,B                 A 'next expression' that
                OR      C                   gives zero is always in
                SCF                         error so jump forward if it
                JR      Z,2AE8,I-CARRY      is so.
                POP     HL                  Take a copy of the
                PUSH    HL                  limit-value. This will be a
                                            'dimension-size' a 'DIM-limit'
                                            or a 'string length'.
                AND     A                   Now compare the result of
                SBC     HL,BC               evaluating the expression against
                                            the limit.
```

The state of the carry flag and the value held in the D register are now manipulated so as to give the appropriate value for the 'error register'.

```
2AE8    I-CARRY LD      A,D                 Fetch the 'old error value'
                SBC     A,+00               Form the 'new error value';
                                            +00 if no error at anytime/
                                            +FF or less if an 'out of
                                            range' error on this pass or on
                                            previous ones.
```

Restore the registers before returning.

```
2AEB    I-RESTORE POP   HL                  Restore HL & DE.
                POP     DE
                RET                         Return; 'error register' is the
                                            A register.
```

THE 'DE,(DE+1)' SUBROUTINE

This subroutine performs the construction - LD DE,(DE+1) - and returns HL pointing to 'DE+2'.

```
2AEE    DE,(DE+1) EX    DE,HL               Use HL for the construction.
                INC     HL                  Point to 'DE+1'.
                LD      E,(HL)              In effect - LD E,(DE+1).
                INC     HL                  Point to 'DE+2'.
                LD      D,(HL)              In effect - LD D,(DE+2).
                RET                         Finished.
```

THE 'GET-HL*DE' SUBROUTINE

Unless syntax is being checked this subroutine calls 'HL=HL*DE' which performs the implied construction.
Overflow of the 16 bits available in the HL register pair gives the report 'out of memory'. This is not exactly the true situation but it implies that the memory is not large enough for the task envisaged by the programmer.

```
2AF4    GET-HL*DE CALL  2530,SYNTAX-Z       Return directly if syntax is
                RET     Z                   being checked.
                CALL    30A9,HL=HL*DE       Perform the multiplication.
                JP      C,1F15,REPORT-4     Report 'Out of memory'.
                RET                         Finished.
```

THE 'LET' COMMAND ROUTINE

This is the actual assignment routine for the LET, READ and INPUT commands.
When the destination variable is a 'newly declared variable' then DEST will point to the first letter of the variable's name as it occurs in the BASIC line. Bit 1 of FLAGX will be set.
However if the destination variable 'exists already' then bit 1 of FLAGX will be reset and DEST will point for a numeric variable to the location before the five bytes of the

'old number'; and for a string variable to the first location of the 'old string'. The use of DEST in this manner applies to simple variables and to elements of arrays.
Bit 0 of FLAGX is set if the destination variable is a 'complete' simple string variable. (Signalling - delete the old copy.)
Initially the current value of DEST is collected and bit 1 of FLAGS tested.

```
2AFF    LET         LD      HL,(DEST)           Fetch the present address in
                                                DEST.
                    BIT     1,(FLAGX)           Jump if handling a variable
                    JR      Z,2B66,L-EXISTS     that 'exists already'.
```

A 'newly declared variable' is being used. So first the length of its name is found.

```
                    LD      BC,+0005            Presume dealing with a
                                                numeric variable - 5 bytes.
```

Enter a loop to deal with the characters of a long name. Any spaces or colour codes in the name are ignored.

```
2B0B    L-EACH-CH   INC     BC                  Add '1' to the counter for
                                                each character of a name.
2B0C    L-NO-SP     INC     HL                  Move along the variable's name.
                    LD      A,(HL)              Fetch the 'present code'.
                    CP      +20                 Jump back if it is a 'space';
                    JR      Z,2B0C,L-NO-SP      thereby Ignoring spaces.
                    JR      NC,2B1F,L-TEST-CH   Jump forward if the code is
                                                +21 to +FF.
                    CP      +10                 Accept, as a final code, those
                    JR      C,2B29,L-SPACES     in the range +00 to +0F.
                    CP      +16                 Also accept the range
                    JR      NC,2B29,L-SPACES    +16 to +1F.
                    INC     HL                  Step past the control code
                                                after any of INK to OVER.
                    JR      2B0C,L-NO-SP        Jump back as these control
                                                codes are treated as spaces.
```

Separate 'numeric' and 'string' names.

```
2B1F    L-TEST -CH  CALL    2C88,ALPHANUM       Is the code alphanumeric?
                    JR      C,2B0B,L-EACH-CH    If It is so then accept it as
                                                a character of a 'long' name.
                    CP      +24                 Is the present code a 'S'?
                    JP      Z,2BC0,L-NEWS       Jump forward as handling a
                                                'newly declared' simple string.
```

The 'newly declared numeric variable' presently being handled will require 'BC' spaces in the variables area for its name and its value. The room is made available and the name of the variable is copied over with the characters being 'marked' as required.

```
2B29    L-SPACES    LD      A,C                 Copy the 'length' to A.
                    LD      HL,(E-LINE)         Make HL point to the
                    DEC     HL                  '80-byte' at the end of the
                                                variables area.
                    CALL    1655,MAKE-ROOM      Now open up the variables area.
                                                Note: In effect 'BC' spaces are
                                                made before the displaced
                                                '80-byte'.
                    INC     HL                  Point to the first 'new' byte.
                    INC     HL                  Make DE point to the second
                    EX      DE,HL               'new' byte.
                    PUSH    DE                  Save this pointer.
                    LD      HL,(DEST)           Fetch the pointer to the
                                                start of the name.
                    DEC     DE                  Make DE point to the first
                                                'new' byte.
                    SUB     +06                 Make B hold the 'number of
                    LD      B,A                 extra letters' that are found
                                                in a 'long name'.
```

```
                    JR      Z,2B4F,L-SINGLE     Jump forward if dealing with
                                                a variable with a 'short name'.
```

The 'extra' codes of a long name are passed to the variables area.

```
2B3E    L-CHAR      INC     HL          Point to each 'extra' code.
                    LD      A,(HL)      Fetch the code.
                    CP      +21         Accept codes from +21 to +FF;
                    JR      C,2B3E,L-CHAR   ignore codes +00 to +20.
                    OR      +20         Set bit 5, as for lower case
                                        letters.
                    INC     DE          Transfer the codes in turn
                    LD      (DE),A      to the 2nd 'new' byte
                                        onwards.
                    DJNZ    2B3E,L-CHAR Go round the loop for all the
                                        'extra' codes.
```

The last code of a 'long' name has to be ORed with +80.

```
                    OR      +80         Mark the code as required
                    LD      (DE),A      and overwrite the last code.
```

The first letter of the name of the variable being handled is now considered.

```
                    LD      A,+C0       Prepare the mark the letter
                                        of a 'long' name.
2B4F    L-SINGLE    LD      HL,(DEST)   Fetch the pointer to the letter.
                    XOR     (HL)        A holds +00 for a 'short'
                                        name and +C0 for a 'long' name.
                    OR      +20         Set bit 5, as for lower case
                                        letters.
                    POP     HL          Drop the pointer now.
```

The subroutine L-FIRST is now called to enter the 'letter' into its appropriate location.

```
                    CALL    2BEA,L-FIRST    Enter the letter and return
                                            with HL pointing to 'new
                                            80-byte'.
```

The 'last value' can now be transferred to the variables area. Note that at this point HL always points to the location after the five locations allotted to the number.
A 'RST 0028' instruction is used to call the CALCULATOR and the 'last value' is deleted. However this value is not overwritten.

```
2B59    L-NUMERIC   PUSH    HL          Save the 'destination' pointer.
                    RST     0028,FP-CALC    Use the calculator.
                    DEFB    +02,delete      This moves STKEND back five
                    DEFB    +38,end-calc    bytes.
                    POP     HL          Restore the pointer.
                    LD      BC,+0005    Give the number a 'length'
                                        of five bytes.
                    AND     A           Make HL point to the first
                    SBC     HL,BC       of the five locations and
                    JR      2BA6,L-ENTER    jump forward to make the
                                            actual transfer.
```

Come here if considering a variable that 'exists already'. First bit 6 of FLAGS is tested so as to separate numeric variables from string or array of string variables.

```
2B66    L-EXISTS    BIT     6,(FLAGS)   Jump forward if handling any
                    JR      Z,2B72,L-DELETES    kind of string variable.
```

For numeric variables the 'new' number overwrites the 'old' number. So first HL has to be made to point to the location after the five bytes of the existing entry. At present HL points to the location before the five bytes.

```
                    LD      DE,+0006    The five bytes of a number +'1'.
                    ADD     HL,DE       HL now points 'after'.
                    JR      2B59,L-NUMERIC  Jump back to make the actual
                                            transfer.
```

The parameters of the string variable are fetched and complete simple strings separated from 'sliced' strings and array strings.

```
2B72    L-DELETE$   LD      HL,(DEST)       Fetch the 'start'. Note: This
                                            line is redundant.
                    LD      BC,(STRLEN)     Fetch the 'length'.
                    BIT     0,(FLAGX)       Jump if dealing with a complete
                    JR      NZ,2BAF,L-ADD$  simple string; the old string will
                                            need to be 'deleted' in this case
                                            only.
```

When dealing with a 'slice' of an existing simple string, a 'slice' of a string from an array of strings or a complete string from an array of strings there are two distinct stages involved. The first is to build up the 'new' string in the work space, lengthening or shortening it as required. The second stage is then to copy the 'new' string to its allotted room in the variables area.
However do nothing if the string has no 'length'.

```
                    LD      A,B             Return if the string is
                    OR      C               a null string.
                    RET     Z
```

Then make the required number of spaces available in the work space.

```
                    PUSH    HL              Save the 'start' (DEST).
                    RST     0030,BC-SPACES  Make the necessary amount of
                                            room in the work space.
                    PUSH    DE              Save the pointer to the
                                            first location.
                    PUSH    BC              Save the 'length' for use later
                                            on.
                    LD      D,H             Make DE point to the last
                    LD      E,L             location.
                    INC     HL              Make HL point 'one past' the
                                            new locations.
                    LD      (HL),+20        Enter a 'space' character.
                    LDDR                    Copy this character into all the
                                            new locations. Finish with HL
                                            pointing to the first new
                                            location.
```

The parameters of the string being handled are now fetched from the calculator stack.

```
                    PUSH    HL              Save the pointer briefly.
                    CALL    2BF1,STK-FETCH  Fetch the 'new' parameters.
                    POP     HL              Restore the pointer.
```

Note: At this point the required amount of room has been made available in the work space for the 'variable in assignment'. e.g. For statement - LET A$(4 to 8)="abcdefg" - five locations have been made.
The parameters fetched above as a 'last value' represent the string that is to be copied into the new locations with Procrustean lengthening or shortening as required.
The length of the 'new' string is compared to the length of the room made available for it.

```
                    EX      (SP),HL         'Length' of new area to HL.
                                            'Pointer' to new area to stack.
                    AND     A               Compare the two 'lengths'
                    SBC     HL,BC           and jump forward if the 'new'
                    ADD     HL,BC           string will fit into the room.
                    JR      NC,2B9B,L-LENGTH i.e. No shortening required.
                    LD      B,H             However modify the 'new'
                    LD      C,L             length if it is too long.
2B9B    L-LENGTH    EX      (SP),HL         'Length' of new area to stack.
                                            'Pointer' to new area to HL.
```

As long as the new string is not a 'null string' it is copied into the work space. Procrustean lengthening is achieved automatically if the 'new' string is shorter than the room available for it.

```
                EX      DE,HL           'Start' of new string to HL.
                                        'Pointer' to new area to DE.
                LD      A,B             Jump forward if the
                OR      C               'new' string is a 'null'
                JR      Z,2BA3,L-IN-W/S string.
                LDIR                    Otherwise move the 'new'
                                        string to the work space.
```

The values that have been saved on the machine stack are restored.

```
2BA3  L-IN-W/S  POP     BC              'Length' of new area.
                POP     DE              'Pointer' to new area.
                POP     HL              The start - the pointer
                                        to the 'variable in assignment'
                                        which was originally in DEST.
                                        L-ENTER is now used to pass
                                        the 'new' string to the variables
                                        area.
```

THE 'L-ENTER' SUBROUTINE

This short subroutine is used to pass either a numeric value, from the calculator stack, or a string, from the work space, to its appropriate position in the variables area.
The subroutine is therefore used for all except 'newly declared' simple strings and 'complete & existing' simple strings.

```
2BA6  L-ENTER   EX      DE,HL           Change the pointers over.
                LD      A,B             Check once again that the
                OR      C               length is not zero.
                RET     Z
                PUSH    DE              Save the destination pointer.
                LDIR                    Move the numeric value or the
                                        string
                POP     HL              Return with the HL register
                RET                     pair pointing to the first byte
                                        of the numeric value or the
                                        string.
```

THE LET SUBROUTINE CONTINUES HERE

When handling a 'complete & existing' simple string the new string is entered as if it were a 'newly declared' simple string before the existing version is 'reclaimed'.

```
2BAF  L-ADD$    DEC     HL              Make HL point to the letter
                DEC     HL              of the variable's name.
                DEC     HL              i.e. DEST - 3.
                LD      A,(HL)          Pick up the letter.
                PUSH    HL              Save the pointer to the 'existing
                                        version'.
                PUSH    BC              Save the 'length' of the
                                        'existing string'.
                CALL    2BC6,L-STRING   Use L-STRING to add the new
                                        string to the variables area.
                POP     BC              Restore the 'length'.
                POP     HL              Restore the pointer.
                INC     BC              Allow one byte for the letter
                INC     BC              and two bytes for the length.
                INC     BC
                JP      19E8,RECLAIM-2  Exit by jumping to RECLAIM-2
                                        which will reclaim the whole
                                        of the existing version.
```

'Newly declared' simple strings are handled as follows:

```
2BC0  L-NEW$    LD      A,+DF           Prepare for the marking of
                                        the variable's letter.
```

		LD	HL,(DEST)	Fetch the pointer to the letter.
		AND	(HL)	Mark the letter as required. L-STRING is now used to add the new string to the variables area.

THE 'L-STRING' SUBROUTINE

The parameters of the 'new' string are fetched, sufficient room is made available for it and the string is then transferred.

2BC6	L-STRING	PUSH	AF	Save the variable's letter
		CALL	2BF1,STK-FETCH	Fetch the 'start' and the 'length' of the 'new' string.
		EX	DE,HL	Move the 'start' to HL.
		ADD	HL,BC	Make HL point 'one-past' the string.
		PUSH	BC	Save the 'length'.
		DEC	HL	Make HL point to the end of the string.
		LD	(DEST),HL	Save the pointer briefly.
		INC	BC	Allow one byte for the letter
		INC	BC	and two bytes for the length.
		INC	BC	
		LD	HL,(E-LINE)	Make HL point to the
		DEC	HL	'80-byte' at the end of the variables area.
		CALL	1655,MAKE-ROOM	Now open up the variables area. **Note:** In effect 'BC' spaces are made before the displaced '80-byte'.
		LD	HL,(DEST)	Restore the pointer to the end of the 'new' string.
		POP	BC	Make a copy of the length
		PUSH	BC	of the 'new' string.
		INC	BC	Add one to the length in case the 'new' string is a 'null' string.
		LDDR		Now copy the 'new' string + one byte.
		EX	DE,HL	Make HL point to the byte
		INC	HL	that is to hold the high-length.
		POP	BC	Fetch the 'length'.
		LD	(HL),B	Enter the high-length.
		DEC	HL	Back one.
		LD	(HL),C	Enter the low-length.
		POP	AF	Fetch the variable’s letter.

THE 'L-FIRST' SUBROUTINE

This subroutine is entered with the letter of the variable, suitably marked, in the A register. The letter overwrites the 'old 80-byte' in the variables area. The subroutine returns with the HL register pair pointing to the 'new 80-byte'.

2BEA	L-FIRST	DEC	HL	Make HL point to the 'old 80-byte'.
		LD	(HL),A	It is overwritten with the letter of the variable.
		LD	HL,(E-LINE)	Make HL point to the 'new 80-byte'.
		DEC	HL	Finished with all the
		RET		'newly declared variables'.

THE 'STK-FETCH' SUBROUTINE

This important subroutine collects the 'last value' from the calculator stack. The five bytes can be either a floating-point number, in 'short' or 'long' form, or set of parameters that define a string.

```
2BF1    STK-FETCH   LD      HL,(STKEND)     Get STKEND.
                    DEC     HL              Back one;
                    LD      B,(HL)          The fifth value.
                    DEC     HL              Back one.
                    LD      C,(HL)          The fourth one.
                    DEC     HL              Back one.
                    LD      D,(HL)          The third value.
                    DEC     HL              Back one.
                    LD      E,(HL)          The second value.
                    DEC     HL              Back one.
                    LD      A,(HL)          The first value.
                    LD      (STKEND),HL     Reset STKEND to its new
                                            position
                    RET                     Finished.
```

THE 'DIM' COMMAND ROUTINE

This routine establishes new arrays in the variables area. The routine starts by searching the existing variables area to determine whether there is an existing array with the same name. If such an array is found then it is 'reclaimed' before the new array is established.
A new array will have all its elements set to zero, if it is a numeric array, or to 'spaces', if it is an array of strings.

```
2C02    DIM         CALL    28B2,LOOK-VARS      Search the variables area.
2C05    D-RPORT-C   JP      NZ,1C8A,REPORT-C    Give report C as there has been
                                                an error.
                    CALL    2530,SYNTAX-Z       Jump forward if in
                    JR      NZ,2C15,D-RUN       'run time'.
                    RES     6,C                 Test the syntax for string arrays
                                                as if they were numeric.
                    CALL    2996,STK-VAR        Check the syntax of the
                                                parenthesised expression.
                    CALL    1BEE,CHECK-END      Move on to consider the
                                                next statement as the syntax
                                                was satisfactory.
```

An 'existing array' is reclaimed.

```
2C15    D-RUN       JR      C,2C1F,D-LETTER     Jump forward if there is no
                                                'existing array'.
                    PUSH    BC                  Save the discriminator byte.
                    CALL    19B8,NEXT-ONE       Find the start of the next
                                                variable
                    CALL    19E8,RECLAIM-2      Reclaim the 'existing array'.
                    POP     BC                  Restore the discriminator byte.
```

The initial parameters of the new array are found.

```
2C1F    D-LETTER    SET     7,C             Set bit 7 in the discriminator
                                            byte.
                    LD      B,+00           Make the dimension counter
                                            zero.
                    PUSH    BC              Save the counter and the
                                            discriminator byte.
                    LD      HL,+0001        The HL register pair is to
                    BIT     6,C             hold the size of the elements
                    JR      NZ,2C2D,D-SIZE  in the array, '1' for a string
                    LD      L,+05           array/ '5' for a numeric array.
2C2D    D-SIZE      EX      DE,HL           Element size DE.
```

The following loop is accessed for each dimension that is specified in the parenthesised expression of the DIM statement. The total number of bytes required for the elements of the array is built up in the DE register pair.

```
2C2E    D-NO-LOOP   RST     0020,NEXT-CHAR      Advance CH-ADD on each pass..
                    LD      H,+FF               Set a 'limit value'.
                    CALL    2ACC,INT-EXP1       Evaluate a parameter.
                    JP      C,2A20,REPORT-3     Give an error if 'out of range'.
                    POP     HL                  Fetch the dimension-counter
                                                and the discriminator byte.
                    PUSH    BC                  Save the parameter on each
                                                pass through the loop.
                    INC     H                   Increase the dimension counter
                                                on each pass also.
                    PUSH    HL                  Restack the dimension-counter
                                                and the discriminator byte.
                    LD      H,B                 The parameter is moved to
                    LD      L,C                 the HL register pair.
                    CALL    2AF4,GET-HL*DE      The byte total is built up
                    EX      DE,HL               in HL and the transferred to
                                                DE.
                    RST     0018,GET-CHAR       Get the present character
                    CP      +2C                 and go around the loop again
                    JR      Z,2C2E,D-NO-LOOP    if there is another dimension.
```

Note: At this point the DE register pair indicates the number of bytes required for the elements of the new array and the size of each dimension is stacked, on the machine stack.
Now check that there is indeed a closing bracket to the parenthesised expression.

```
                    CP      +29                 Is it a ')'?
                    JR      NZ,2C05,D-REPORT-C  Jump back if not so.
                    RST     0020,NEXT-CHAR      Advance CH-ADD past it.
```

Allowance is now made for the dimension-sizes.

```
                    POP     BC                  Fetch the dimension-counter
                                                and the discriminator byte.
                    LD      A,C                 Pass the discriminator byte
                                                to the A register for later.
                    LD      L,B                 Move the counter to L.
                    LD      H,+00               Clear the H register.
                    INC     HL                  Increase the dimension-
                    INC     HL                  counter by two and double the
                    ADD     HL,HL               result and form the
                    ADD     HL,DE               correct overall length for
                                                the variable by adding the
                                                element byte total.
                    JP      C,1F15,REPORT-4     Give the report 'Out of
                                                memory' if required.
                    PUSH    DE                  Save the element byte total.
                    PUSH    BC                  Save the dimension counter
                                                and the discriminator byte.
                    PUSH    HL                  Save the overall length also.
                    LD      B,H                 Move the overall length to BC.
                    LD      C,L
```

The required amount of room is made available for the new array at the end of the variables area.

```
                    LD      HL,(E-LINE)         Make the HL register pair
                    DEC     HL                  point to the '80-byte'.
                    CALL    1655,MAKE-ROOM      The room is made available.
                    INC     HL                  HL is made to point to the first
                                                new location.
```

The parameters are now entered.

```
                    LD      (HL),A      The letter, suitably marked,
                                        is entered first.
                    POP     BC          The overall length is fetched
                    DEC     BC          and decreased by '3'.
                    DEC     BC
                    DEC     BC
                    INC     HL          Advance HL.
                    LD      (HL),C      Enter the low length.
                    INC     HL          Advance HL.
                    LD      (HL),B      Enter the high length.
                    POP     BC          Fetch the dimension counter.
                    LD      A,B         Move it to the A register.
                    INC     HL          Advance HL.
                    LD      (HL),A      Enter the dimension count.
```

The elements of the new array are now 'cleared'.

```
                    LD      H,D         HL is made to point to the
                    LD      L,E         last location of the array
                    DEC     DE          and DE to the location before
                                        that one.
                    LD      (HL),+00    Enter a zero into the last
                    BIT     6,C         location but overwrite it
                    JR      Z,2C7C,DIM-CLEAR
                                        with 'space' if dealing
                    LD      (HL),+20    with an array of strings.
2C7C    DIM-CLEAR   POP     BC          Fetch the element byte total.
                    LDDR                Clear the array + one extra
                                        location.
```

The 'dimension-sizes' are now entered.

```
2C7F    DIM-SIZES   POP     BC          Get a dimension-size.
                    LD      (HL),B      Enter the high byte.
                    DEC     HL          Back one.
                    LD      (HL),C      Enter the low byte.
                    DEC     HL          Back one.
                    DEC     A           Decrease the dimension
                                        counter.
                    JR      NZ,2C7F,DIM-SIZES
                                        Repeat the operation until all
                                        the dimensions have been
                    RET                 considered; then return.
```

THE 'ALPHANUM' SUBROUTINE

This subroutine returns with the carry flag set if the present value of the A register denotes a valid digit or letter.

```
2C88    ALPHANUM    CALL    2D1B,NUMERIC
                                        Test for a digit; carry will be
                                        reset for a digit.
                    CCF                 Complement the carry flag.
                    RET     C           Return if a digit; otherwise
                                        continue on into 'ALPHA'.
```

THE 'ALPHA' SUBROUTINE

This subroutine returns with the carry flag set if the present value of the A register denotes a valid letter of the alphabet.

```
2C8D    ALPHA       CP      +41         Test against 41 hex, the code
                                        for 'A'
                    CCF                 Complement the carry flag.
                    RET     NC          Return if not a valid character
                                        code.
                    CP      +5B         Test against 5B hex, 1 more
                                        than code for 'Z'.
                    RET     C           Return if an upper case letter.
                    CP      +61         Test against 61 hex, the code
                                        for 'a'.
```

```
                CCF                         Complement the carry flag.
                RET     NC                  Return if not a valid character
                                            code.
                CP      +7B                 Test against 7B hex, 1 more
                                            than the code for 'z'.
                RET                         Finished.
```

THE 'DECIMAL TO FLOATING POINT' SUBROUTINE

As part of syntax checking decimal numbers that occur in a BASIC line are converted to their floating-point forms. This subroutine reads the decimal number digit by digit and gives its result as a 'last value' on the calculator stack. But first it deals with the alternative notation BIN, which introduces a sequence of 0's and 1's giving the binary representation of the required number.

```
2C9B  DEC-TO-FP   CP      +C4                 Is the character a 'BIN'?
                  JR      NZ,2CB8,NOT-BIN     Jump if it is not 'BIN'.
                  LD      DE,+0000            Initialise result to zero in DE.
2CA2  BIN-DIGIT   RST     0020,NEXT-CHAR      Get the next character.
                  SUB     +31                 Subtract the character code for
                                              '1'.
                  ADC     A,+00               0 now gives 0 with carry set; 1
                                              gives 0 with carry reset.
                  JR      NZ,2CB3,BIN-END     Any other character causes a
                                              jump to BIN-END and will be
                                              checked for syntax during or
                                              after scanning.
                  EX      DE,HL               Result so far to HL now.
                  CCF                         Complement the carry flag.
                  ADC     HL,HL               Shift the result left, with the
                                              carry going to bit 0.
                  JP      C,31AD,REPORT-6     Report overflow if more than
                                              65535.
                  EX      DE,HL               Return the result so far to DE.
                  JR      2CA2,BIN-DIGIT      Jump back for next 0 or 1.
2CB3  BIN-END     LD      B,D                 Copy result to BC for stacking.
                  LD      C,E
                  JP      2D2B,STACK-BC       Jump forward to stack the
                                              result.
```

For other numbers, first any integer part is converted; if the next character is a decimal, then the decimal fraction is considered.

```
2CB8  NOT-BIN     CP      +2E                 Is the first character a '.'?
                  JR      Z,2CCB,DECIMAL      If so, jump forward.
                  CALL    2D3B,INT-TO-FP      Otherwise, form a 'last value' of
                                              the integer.
                  CP      +2E                 Is the next character a '.'?
                  JR      NZ,2CEB,E-FORMAT    Jump forward to see if it is an 'E'.
                  RST     0020,NEXT-CHAR      Get the next character.
                  CALL    2D1B,NUMERIC        Is it a digit?
                  JR      C,2CEB,E-FORMAT     Jump if not (e.g. 1.E4 is allowed).
                  JR      2CD5,DEC-STO-1      Jump forward to deal with the
                                              digits after the decimal point.
2CCB  DECIMAL     RST     0020,NEXT-CHAR      If the number started with a
                  CALL    2D1B,NUMERIC        decimal, see if the next
                                              character is a digit.
2CCF  DEC-RPT-C   JP      C,1C8A,REPORT-C     Report the error if it is not.
                  RST     0028,FP-CALC        Use the calculator to stack zero
                  DEFB    +A0,stk-zero        as the integer part of such
                  DEFB    +38,end-calc        numbers.
2CD5  DEC-STO-1   RST     0028,FP-CALC        Use the calculator again.
                  DEFB    +A1,stk-one         Find the floating-point form of
                  DEFB    +C0,st-mem-0        the decimal number '1', and
```

```
                DEFB    +02,delete          save it in the memory area.
                DEFB    +38,end-calc
2CDA  NXT-DGT-1 RST     0018,GET-CHAR       Get the present character.
                CALL    2D22,STK-DIGIT      If it is a digit then stack it.
                JR      C,2CEB,E-FORMAT     If not jump forward.
                RST     0028,FP-CALC        Now use the calculator.
                DEFB    +E0,get-mem-0       For each passage of the loop,
                DEFB    +A4,stk-ten         the number saved in the memory
                DEFB    +05,division        area is fetched, divided by 10
                DEFB    +C0,st-mem-0        and restored: i.e. going from .1
                                            to .01 to .001 etc.
                DEFN    +04,multiply        The present digit is multiplied
                DEFB    +0F,addition        by the 'saved number' and
                DEFB    +38,end-calc        added to the 'last value'.
                RST     0020,NEXT-CHAR      Get the next character.
                JR      2CDA,NXT-DGT-1      Jump back (one more byte than
                                            needed) to consider it.
```

Next consider any 'E notation', i.e. the form xEm or xem where m is a positive or negative integer.

```
2CEB  E-FORMAT  CP      +45                 Is the present character an 'E'?
                JR      Z,2CF2,SIGN-FLAG    Jump forward if it is.
                CP      +65                 Is it an 'e'?
                RET     NZ                  Finished unless it is so.
2CF2  SIGN-FLAG LD      B,+FF               Use B as a sign flag, FF for '+'.
                RST     0020,NEXT-CHAR      Get the next character.
                CP      +2B                 Is it a '+'?
                JR      Z,2CFE,SIGN-DONE    Jump forward.
                CP      +2D                 Is it a '-'?
                JR      NZ,2CFF,ST-E-PART   Jump if neither '+' not '-'.
                INC     B                   Change the sign of the flag.
2CFE  SIGN-DONE RST     0020,NEXT-CHAR      Point to the first digit.
2CFF  ST-E-PART CALL    2D1B,NUMERIC        Is it indeed a digit?
                JR      C,2CCF,DEC-RPT-C    Report the error if not.
                PUSH    BC                  Save the flag in B briefly.
                CALL    2D3B,INT-TO-FP      Stack ABS m, where m is the
                                            exponent.
                CALL    2DD5,FP-TO-A        Transfer ABS m to A.
                POP     BC                  Restore the sign flag to B.
                JP      C,31AD,REPORT-6     Report the overflow now if
                AND     A                   ABS m is greater than 255 or
                JP      M,31AD,REPORT-6     indeed greater than 127 (other
                                            values greater than about 39 will
                                            be detected later).
                INC     B                   Test the sign flag in B; '+'
                                            (i.e. +FF) will now set the zero
                                            flag.
                JR      Z,2D18,E-FP-JUMP    Jump if sign of m is '+'.
                NEG                         Negate m if sign is '-'.
2D18  E-FP-JUMP JP      2D4F,E-TOO-FP       Jump to assign to the 'last value'
                                            the result of x*10^m.
```

THE 'NUMERIC' SUBROUTINE

This subroutine returns with the carry flag reset if the present value of the A register denotes a valid digit.

```
2D1B  NUMERIC   CP      +30                 Test against 30 hex, the code
                                            for '0'.
                RET     C                   Return if not a valid character
                                            code.
                CP      +3A                 Test against the upper limit.
                CCF                         Complement the carry flag.
                RET                         Finished.
```

THE 'STK DIGIT' SUBROUTINE

This subroutine simply returns if the current value held in the A register does not represent a digit but if it does then the floating-point form for the digit becomes the 'last value' on the calculator stack.

```
2D22    STK-DIGIT   CALL    2D1B,NUMERIC    Is the character a digit?
                    RET     C               Return if not in range.
                    SUB     +30             Replace the code by the actual
                                            digit.
```

THE 'STACK-A' SUBROUTINE

This subroutine gives the floating-point form for the absolute binary value currently held in the A register.

```
2D28    STACK-A     LD      C,A             Transfer the value to the C
                                            register.
                    LD      B,+00           Clear the B register
```

THE 'STACK-BC' SUBROUTINE

This subroutine gives the floating-point form for the absolute binary value currently held in the BC register pair.

The form used in this and hence in the two previous subroutines as well is the one reserved in the Spectrum for small integers n, where -65535 <= n <= 65535. The first and fifth bytes are zero; the third and fourth bytes are the less significant and more significant bytes of the 16 bit integer n in two's complement form (if n is negative, these two bytes hold 65536+n); and the second byte is a sign byte, 00 for '+' and FF for '-'.

```
2D2B    STACK-BC    LD      IY,+5C3A        Re-initialise IY to ERR-NR.
                    XOR     A               Clear the A register.
                    LD      E,A             And the E register, to indicate
                                            '+'.
                    LD      D,C             Copy the less significant byte to
                                            D.
                    LD      C,B             And the more significant byte
                                            to C.
                    LD      B,A             Clear the B register.
                    CALL    2AB6,STK-STORE  Now stack the number.
                    RST     0028,FP-CALC    Make HL point to
                    DEFB    +38,end-calc    STKEND-5.
                    AND     A               Clear the carry flag.
                    RET                     Finished.
```

THE 'INTEGER TO FLOATING-POINT' SUBROUTINE

This subroutine returns a 'last value' on the calculator stack that is the result of converting an integer in a BASIC line, i.e. the integer part of the decimal number or the line number, to its floating-point form.

Repeated calls to CH-ADD+1 fetch each digit of the integer in turn. An exit is made when a code that does not represent a digit has been fetched.

```
2D3B    INT-TO-FP   PUSH    AF              Save the first digit - in A.
                    RST     0028,FP-CALC    Use the calculator.
                    DEFB    +A0,stk-zero    The 'last value' is now zero.
                    DEFB    +38,end-calc
                    POP     AF              Restore the first digit.
```

Now a loop is set up. As long as the code represents a digit then the floating-point form is found and stacked under the 'last value'. The 'last value' is then multiplied by decimal 10 and added to the 'digit' to form a new 'last value' which is carried back to the start of the loop.

```
2D40    NXT-DGT-2   CALL    2D22,STK-DIGIT  If the code represents a digit
                    RET     C               then stack the floating-point
                                            form.
                    RST     0028,FP-CALC    Use the calculator.
                    DEFB    +01,exchange    'Digit' goes under 'last value'.
                    DEFB    +A4,stk-ten     Define decimal 10.
                    DEFB    +04,multiply    'Last value' = 'last value' *10.
                    DEFB    +0F,addition    'Last value' = 'last value+
                                            'digit'.
                    DEFB    +38,end-calc
                    CALL    0074,CH-ADD+1   The next code goes into A.
                    JR      2D40,NXT-DGT-2  Loop back with this code.
```

THE ARITHMETIC ROUTINES

THE 'E-FORMAT TO FLOATING-POINT' SUBROUTINE

(Offset 3C - see CALCULATE below: 'e-to-fp')

This subroutine gives a 'last value' on the top of the calculator stack that is the result of converting a number given in the form xEm, where m is a positive or negative integer. The subroutine is entered with x at the top of the calculator stack and m in the A register.

The method used is to find the absolute value of m, say p, and to multiply or divide x by 10^p according to whether m is positive or negative.

To achieve this, p is shifted right until it is zero, and x is multiplied or divided by 10^(2^n) for each set bit b(n) of p. Since p is never much more than decimal 39, bits 6 and 7 of p will not normally be set.

2D4F	E-TO-FP	RLCA		Test the sign of m by rotating
		RRCA		bit 7 of A into the carry
				without changing A.
		JR	NC,2D55,E-SAVE	Jump if m is positive.
		CPL		Negate m in A without
		INC	A	disturbing the carry flag.
2D55	E-SAVE	PUSH	AF	Save m in A briefly.
		LD	HL,+5C92	This is MEMBOT: a sign flag is
		CALL	350B,FP-0/1	now stored in the first byte of
				mem-0, i.e. 0 for '+' and 1 for
		RST	0028,FP-CALC	The stack holds x.
		DEFB	+A4,stk-ten	x,10 (decimal)
		DEFB	+38,end-calc	x,10
		POP	AF	Restore m in A.
2D60	E-LOOP	SRL	A	In the loop, shift out the next
				bit of m, modifying the carry
				and zero flags appropriately;
		JR	NC,2D71,E-TST-END	jump if carry reset.
		PUSH	AF	Save the rest of m and the flags.
		RST	0028,FP-CALC	The stack holds x' and
				10^(2^n), where x' is an
				interim stage in the multiplica-
				tion of x by 10^m, and n=
				0,1,2,3,4 or 5.
		DEFB	+C1,st-mem-1	(10^(2^n) is copied to mem-1).
		DEFB	+E0,get-mem-0	x', 10^(2^n), (1/0)
		DEFB	+00,jump-true	x', 10^(2^n)
		DEFB	+04,to E-DIVSN	x', 10^(2^n)
		DEFB	+04,multiply	x'*10^(2^n)= x''
		DEFB	+33,jump	x''
		DEFB	+02,to E-FETCH	x''
2D6D	E-DIVSN	DEFB	+05,division	x/10^(2^n)=x'' (x'' is N'*10^
				(2^n) or x'/10^(2^n)
				according as m is '+' ot '-').
2D6E	E-FETCH	DEFB	+E1,get-mem-1	x'', 10^(2^n)
		DEFB	+38,end-calc	x'', 10^(2^n)
		POP	AF	Restore the rest of m in A, and
				the flags.
2D71	E-TST-END	JR	Z,2D7B,E-END	Jump if m has been reduced to
				zero.
		PUSH	AF	Save the rest of m in A.
		RST	0028,FP-CALC	x'', 10^(2^n)
		DEFB	+31,duplicate	x'', 10^(2^n), 10^(2^n)
		DEFB	+04,multiply	x'', 10^(2^(n+1))
		DEFB	+38,end-calc	x'', 10^(2^(n+1))
		POP	AF	Restore the rest of m in A.
		JR	2D60,E-LOOP	Jump back for all bits of m.
2D7B	E-END	RST	0028,FP-CALC	Use the calculator to delete the

```
                DEFB    +02,delete      final power of 10 reached,
                DEFB    +28,end-calc    leaving the 'last value' x*10^m
                RET                     on the stack
```

THE 'INT-FETCH' SUBROUTINE

This subroutine collects in DE a small integer n (-65535<=n<=65535) from the location addressed by HL: i.e. n is normally the first (or second) number at the top of the calculator stack; but HL can alls access (by exchange with DE) a number which has been deleted from the stack. The subroutine does not itself delete the number from the stack or from memory; it returns HL pointing to the fourth byte of the number in its original position.

```
2D7F    INT-FETCH   INC     HL          Point to the sign byte of the
                                        number.
                    LD      C,(HL)      Copy the sign byte to C.
```

The following mechanism will twos complement the number if it is negative (C is FF) but leave it unaltered if it is positive (C is 00)

```
                    INC     HL          Point to the less significant
                                        byte.
                    LD      A,(HL)      Collect the byte in A.
                    XOR     C           Ones complement it if negative
                    SUB     C           This adds 1 for negative
                                        numbers; it sets the carry unless
                                        the byte was 0.
                    LD      E,A         Less significant byte to E now.
                    INC     HL          Point to the more significant
                                        byte.
                    LD      A,(HL)      Collect it in A.
                    ADC     A,C         Finish two complementing in
                                        the case of a negative number;
                                        note that the carry is always
                                        left reset.
                    LD      D,A         More significant byte to D now.
                    RET                 Finished.
```

THE 'INT-STORE' SUBROUTINE

This subroutine stores a small integer n (-65535<=n<=65535) in the location addressed by HL and the four following locations: i.e. n replaces the first (or second) number at the top of the calculator stack. The subroutine returns HL pointing to the first byte of n on the stack.

```
2D8C    P-INT-STO   LD      C,+00       This entry point would store a
                                        number known to be positive
2D8E    INT-STORE   PUSH    HL          The pointer to the first location
                                        is saved.
                    LD      (HL),+00    The first byte is set to zero.
                    INC     HL          Point to the second location.
                    LD      (HL),C      Enter the second byte.
```

The same mechanism is now used as in 'INT-FETCH' to twos complement negative numbers. This is needed e.g. before and after the multiplication of small integers. Addition is however performed without any further twos complementing before or afterwards.

```
                    INC     HL          Point to the third location.
                    LD      A,E         Collect the less significant
                                        byte.
                    XOR     C           Twos complement it if the
                    SUB     C           number is negative
                    LD      (HL),A      Store the byte.
                    INC     HL          Point to the fourth location.
                    LD      A,D         Collect the more significant
                                        byte.
                    ADC     A,C         Twos complement it if the
                    XOR     C           number is negative
```

```
                LD      (HL),A          Store the byte.
                INC     HL              Point to the fifth location.
                LD      (HL),+00        The fifth byte is set to zero.
                POP     HL              Return with HL pointing to the
                RET     first byte on n on the stack
```

THE 'FLOATING-POINT TO BC' SUBROUTINE

This subroutine is called from four different places for various purposes and is used to compress the floating-point 'last value' into the BC register pair. If the result is too large, i.e. greater than 65536 decimal, then the subroutine returns with the carry flag set. If the 'last value' is negative then the zero flag is reset. The low byte of the result is also copied to the A register.

```
2DA2    FP-TO-BC    RST     0028,FP-CALC    Use the calculator to make HL
                    DEFB    +38,end-calc    point to STKEND-5
                    LD      A,(HL)          Collect the exponent byte of
                    AND     A               the 'last value'; jump if it is
                    JR      Z,2DAD,FP-DELETE zero, indicating a 'small integer'.
                    RST     0028,FP-CALC    Now use the calculator to round
                    DEFB    +A2,stk-half    the 'last value' to the nearest
                    DEFB    +0F,addition    integer, which also changes it to
                    DEFB    +27,int         'small integer' form on the
                    DEFB    +38,end-calc    calculator stack if that is pos-
                                            sible, i.e. if -65535.5 <=
                                            x <65535.3
2DAD    FP-DELETE   RST     0028,FP-CALC    Use the calculator to delete the
                    DEFB    +92,delete      integer from the stack; DE still
                    DEFB    +38,end-calc    points to it in memory (at
                                            STKEND).
                    PUSH    HL              Save both stack pointers.
                    PUSH    DE
                    EX      DE,HL           HL now points to the number.
                    LD      B,(HL)          Copy the first byte to B.
                    CALL    2D7F,INT-FETCH  Copy bytes 2, 3 and 4 to C, E
                                            and D.
                    XOR     A               Clear the A register.
                    SUB     B               This sets the carry unless B is
                                            zero.
                    BIT     7,C             This sets the zero flag if the
                                            number is positive (NZ denotes
                                            negative).
                    LD      B,D             Copy the high byte to B.
                    LD      C,E             And the low byte to C.
                    LD      A,E             Copy the low byte to A too.
                    POP     DE              Restore the stack pointers.
                    POP     HL
                    RET                     Finished.
```

THE 'LOG (2^A)' SUBROUTINE

This subroutine is called by the 'PRINT-FP' subroutine to calculate the approximate number of digits before the decimal in x, the number to be printed, or, if there are no digits before the decimal, then the approximate number of leading zeros after the decimal. It is entered with the A register containing e', the true exponent of x, or e'-2, and calculates z=log to the base 10 of (2^A). It then sets A equal to ABS INT (Z + 0.5), as required, using FP-TO-A for this purpose.

```
2DC1    LOG(2^A)    LD      D,A             The integer A is stacked, either
                    RLA                     as 00 00 A 00 00 (for positive
                    SBC     A,A             A) or as 00 FF A FF 00 (for
                                            negative A).
                    LD      E,A             These bytes are first loaded into
                    LD      C,A             A, E, D, C, B and then STK-
                    XOR     A               STORE is called to put the
                    LD      B,A             number on the calculator stack.
```

```
                CALL    2AB6,STK-STORE
                RST     0028,FP-CALC        The calculator is used
                DEFB    +34,stk-data        Log 2 to the base 10 is now
                                            stacked.
                DEFB    +EF,exponent +7F    The stack now holds a, log 2.
                DEFB    +1A,+20,+9A,+85
                DEFB    +04,multiply        A*log 2 i.e. log (2^A)
                DEFB    +27,int             INT log (2^A)
                DEFB    +38,end-calc
```

The subroutine continues on into FP-TO-A to complete the calculation.

THE 'FLOATING-POINT TO A' SUBROUTINE

This short but vital subroutine is called at least 8 times for various purposes. It uses the last but one subroutine, FP-TO-BC, to get the 'last value' into the A register where this is possible. It therefore tests whether the modulus of the number rounds to more than 255 and if it does the subroutine returns with the carry flag set. Otherwise it returns with the modulus of the number, rounded to the nearest integer, in the A register, and the zero flag set to imply that the number was positive, or reset to imply that it was negative.

```
2DD5    FP-TO-A     CALL    2DA2,FP-TO-BC       Compress the 'last value' into
                                                BC.
                    RET     C                   Return if out of range already.
                    PUSH    AF                  Save the result and the flags.
                    DEC     B                   Again it will be out of range
                    INC     B                   if the B register does not hold
                                                zero.
                    JR      Z,2DE1,FP-A-END     Jump if in range.
                    POP     AF                  Fetch the result and the flags
                    SCF                         Signal the result is out of range.
                    RET                         Finished - unsuccessful.
2DE1    FP-A-END    POP     AF                  Fetch the result and the flags.
                    RET                         Finished - successful.
```

THE 'PRINT A FLOATING-POINT NUMBER' SUBROUTINE

This subroutine is called by the PRINT command routine at 2039 and by STR$ at 3630, which converts to a string the number as it would be printed. The subroutine prints x, the 'last value' on the calculator stack. The print format never occupies more than 14 spaces. The 8 most significant digits of x, correctly rounded, are stored in an ad hoc print buffer in mem-3 and mem-4. Small numbers, numerically less than 1, and large numbers, numerically greater than 2 ^ 27, are dealt with separately. The former are multiplied by 10 ^ n, where n is the approximate number of leading zeros after the decimal, while the latter are divided by 10 ^ (n-7), where n is the approximate number of digits before the decimal. This brings all numbers into the middle range, and the numbers of digits required before the decimal is built up in the second byte of mem-5. Finally the printing is done, using E-format if there are more than 8 digits before the decimal or, for small numbers, more than 4 leading zeros after the decimal.

The following program shows the range of print formats:

```
10 FOR a=-11 TO 12: PRINT SGN a*9^a,: NEXT a
```

i. First the sign of x is taken care of:
If X is negative, the subroutine jumps to PF-NEGATIVE, takes ABS x and prints the minus sign.
If x is zero, x is deleted from the calculator stack, a '0' is printed and a return is made from the subroutine.
If x is positive, the subroutine just continues.

```
2DE3    PRINT-FP    RST     0028,FP-CALC        Use the calculator
                    DEFB    +31,duplicate       x,x
                    DEFB    +36,less-0          x, (1/0) Logical value of x.
                    DEFB    +00,jump-true       x
                    DEFB    +0B,to PF-NEGTVE    x
                    DEFB    +31,duplicate       x,x
                    DEFB    +37,greater-0       x, (1/0) Logical value of X.
```

```
                DEFB    +00,jump-true       x
                DEFB    +0D,to PF-POSTVE    x Hereafter x'=ABS x.
                DEFB    +02,delete          -
                DEFB    +38,end-calc        -
                LD      A,+30               Enter the character code for '0'.
                RST     0010,PRINT-A-1      Print the '0'.
                RET                         Finished as the 'last value' is
                                            zero.
2DF2  PF-NEGTVE DEFB    +2A,abs             x' x'=ABS x.
                DEFB    +38,end-calc        x'
                LD      A,+2D               Enter the character code for '-'.
                RST     0010,PRINT-A-1      Print the '-'.
                RST     0028,FP-CALC        Use the calculator again.
2DF8  PF-POSTVE DEFB    +A0,stk-zero        The 15 bytes of mem-3, mem-4
                DEFB    +C3,st-mem-3        and mem-5 are now initialised to
                DEFB    +C4,st-mem-4        zero to be used for a print
                DEFB    +C5,st-mem-5        buffer and two counters.
                DEFB    +02,delete          The stack is cleared, except for
                                            x'.
                DEFB    +38,end-calc        x'
                EXX                         H'L', which is used to hold
                PUSH    HL                  calculator offsets, (e.g. for
                EXX                         'STR$') is saved on the machine
                                            stack.
```

ii. This is the start of a loop which deals with large numbers. However every number x is first split into its integer part i and the fractional part f. If i is a small integer, i.e. if -65535 <= i <= 65535, it is stored in D'E' for insertion into the print buffer.

```
2E01  PF-LOOP   RST     0028,FP-CALC        Use the calculator again.
                DEFB    +31,duplicate       x' x'
                DEFB    +27,int             x', INT (x')=i
                DEFB    +C2,st-mem-2        (i is stored in mem-2).
                DEFB    +03,subtract        x'-i=f
                DEFB    +E2,get-mem-2       f,i
                DEFB    +01,exchange        i,f
                DEFB    +C2,st-mem-2        (f is stored in mem-2).
                DEFB    +03,delete          i
                DEFB    +38,end-calc        i
                LD      A,(HL)              Is i a small integer (first byte
                AND     A                   zero) i.e. is ABS i <= 65535?
                JR      NZ,2E56,PF-LARGE    Jump if it is not
                CALL    2D7F,INT-FETCH      i is copied to DE (i, like x', >=0).
                LD      B,+10               B is set to count 16 bits.
                LD      A,D                 D is copied to A for testing:
                AND     A                   Is it zero?
                JR      NZ,2E1E,PF-SAVE     Jump if it is not zero.
                OR      E                   Now test E.
                JR      Z,2E24,PF-SMALL     Jump if DE zero: x is a pure
                                            fraction.
                LD      D,E                 Move E to D and set B for 8
                LD      B,+08               bits: D was zero and E was not.
2E1E  PF-SAVE   PUSH    DE                  Transfer DE to D'E', via the
                EXX                         machine stack, to be moved
                POP     DE                  into the print buffer at
                EXX                         PF-BITS.
                JR      2E78,PF-BITS        Jump forward.
```

iii. Pure fractions are multiplied by 10^n, where n is the approximate number of leading zeros after the decimal; and -n is added to the second byte of mem-5, which holds the number of digits needed before the decimals; a negative number here indicates leading zeros after the decimal;

```
2E24  PF-SMALL  RST     0028,FP-CALC        i (i=zero here),
                DEFB    +E2,get-mem-2       i,f
```

```
                DEFB    +38,end-calc        i, f
```

Note that the stack is now unbalanced. An extra byte 'DEFB +02, delete' is needed at 2E25, immediately after the RST 0028. Now an expression like "2" +STR$ 0.5 is evaluated incorrectly as 0.5; the zero left on the stack displaces the "2" and is treated as a null string. Similarly all the string comparisons can yield incorrect values if the second string takes the form STR$ x where x is numerically less than 1; e.g. the expression "50"<STR$ 0 .1 yields the logical value "true"; once again "" is used instead of "50".

```
                LD      A,(HL)              The exponent byte e of f is
                                            copied to A.
                SUB     +7E                 A becomes e - 126 dec i.e.
                                            e'+2, where e' is the true
                                            exponent of f.
                CALL    2DC1,LOG (2^A)      The construction A = ABS INT
                                            (LOG (2^A)) is performed
                                            (LOG is to base 10); i.e. A=n,
                LD      D,A                 say: n is copied from A to D.
                LD      A,(mem-5-2nd)       The current count is collected
                SUB     D                   from the second byte of mem-5
                LD      (mem-5-2nd),A       and n is subtracted from it.
                LD      A,D                 n is copied from D to A.
                CALL    2D4F,E-TO-FP        y=f*10^n is formed and
                                            stacked.
                RST     0028,FP-CALC        i, y
                DEFB    +31,duplicate       i, y, y
                DEFB    +27,int             i, y, (INT (y) = i2
                DEFB    +C1,st-mem-1        (i2 is copied to mem-1).
                DEFB    +03,subtract        i, y - i2
                DEFB    +E1,get-mem-1       i, y - i2, i2
                DEFB    +38,end-calc        i, f2, i2 (f2 = y - i2)
                CALL    2DD5,FP-TO-A        i2 is transferred from the stack
                                            to A.
                PUSH    HL                  The pointer to f2 is saved.
                LD      (mem-3-1st),A       i2 is stored in the first byte of
                                            mem-3: a digit for printing.
                DEC     A                   i2 will not count as a digit for
                RLA                         printing if it is zero; A is
                SBC     A,A                 manipulated so that zero will
                INC     A                   produce zero but a non-zero
                                            digit will produce 1.
                LD      HL,+5CAB            The zero or one is inserted into
                LD      (HL),A              the first byte of mem-5 (the no.
                INC     HL                  of digits for printing) and added
                ADD     A,(HL)              to the second byte of mem-5
                LD      (HL),A              (the number of digits before the
                                            decimal).
                POP     HL                  The pointer to f2 is restored.
                JP      2ECF,PF-FRACTN      Jump to store f2 in buffer (HL
                                            now points to f2, DE to i2).
```

iv. Numbers greater than 2 ^ 27 are similarly multiplied by 2 ^ (-n+7), reducing the number of digits before the decimal to 8, and the loop is re-entered at PF-LOOP.

```
2E56    PF-LARGE    SUB     +80             e - 80 hex = e', the true
                                            exponent of i.
                    CP      +1C             Is e' less than 28 decimal?
                    JR      C,2E6F,PF-MEDIUM Jump if it is less.
                    CALL    2DC1,LOG (2^A)  n is formed in A.
                    SUB     +07             And reduced to n - 7.
                    LD      B,A             Then copied to B.
                    LD      HL,+5CAC        n - 7 is added in to the second
                    ADD     A,(HL)          byte of mem-5, the number of
                    LD      (HL),A          digits required before the
```

```
                                                  decimal in x.
                    LD          A,B               Then i is multiplied by
                                                  10^(-n+7)
                    NEG                           This will bring it into medium
                    CALL        2D4F,E-TO-FP      range for printing.
                    JR          2E01,PF-LOOP      Round the loop again to deal
                                                  with the now medium-sized
                                                  number.
```

v. The integer part of x is now stored in the print buffer in mem-3 and mem-4.

```
2E6F    PF-MEDIUM   EX          DE,HL             DE now points to i, HL to f.
                    CALL        2FBA,FETCH-TWO    The mantissa of i is now in
                                                  D',E',D,E.
                    EXX                           Get the exchange registers.
                    SET         7,D               True numerical bit 7 to D'.
                    LD          A,L               Exponent byte e of i to A.
                    EXX                           Back to the main registers.
                    SUB         +80               True exponent e'=e - 80 hex to
                                                  A.
                    LD          B,A               This gives the required bit
                                                  count.
```

Note that the case where i us a small integer (less than 65536) re-enters here.

```
2E7B    PF-BITS     SLA         E                 The mantissa of i is now rotated
                    RL          D                 left and all the bits of i are thus
                    EXX                           shifted into mem-4 and each
                    RL          E                 byte of mem-4 is decimal
                                                  adjusted at each shift.
                    RL          D                 All four bytes of i.
                    EXX                           Back to the main registers.
                    LD          HL,+5CAA          Address of fifth byte of mem-4
                    LD          C,+05             to HL; count of 5 bytes to C.
2E8A    PF-BYTES    LD          A,(HL)            Get the byte of mem-4.
                    ADC         A,A               Shift it left, taking in the new
                                                  bit.
                    DAA                           Decimal adjust the byte.
                    LD          (HL),A            Restore it to mem-4.
                    DEC         HL                Point to next byte of mem-4.
                    DEC         C                 Decrease the byte count by one.
                    JR          NZ,2E8A,PF-BYTES  Jump for each byte of mem-4.
                    DJNZ        2E7B,PF-BITS      Jump for each bit of INT (x).
```

Decimal adjusting each byte of mem-4 gave 2 decimal digits per byte, there being at most 9 digits. The digits will now be re-packed, one to a byte, in mem-3 and mem-4, using the instruction RLD.

```
                    XOR         A                 A is cleared to receive the digits.
                    LD          HL,+5CA6          Source address: first byte of
                                                  mem-4.
                    LD          DE,+5CA1          Destination: first byte of
                                                  mem-3.
                    LD          B,+09             There are at most 9 digits.
                    RLD                           The left nibble of mem-4 is
                                                  discarded.
                    LD          C,+FF             FF in C will signal a leading
                                                  zero, 00 will signal a non-leading
                                                  zero.
2EA1    PF-DIGITS   RLD                           Left nibble of (HL) to A, right
                                                  nibble of (HL) to left.
                    JR          NZ,2EA9,PF-INSERT Jump if digit in A is not zero.
                    DEC         C                 Test for a leading zero:
                    INC         C                 it will now give zero reset.
                    JR          NZ,2EB3,PF-TEST-2 Jump it it was a leading zero.
2EA9    PF-INSERT   LD          (DE),A            Insert the digit now.
```

```
                    INC     DE              Point to next destination.
                    INC     (mem-5-1st)     One more digit for printing, and
                    INC     (mem-5-2nd)     one more before the decimal.
                    LD      C,+00           Change the flag from leading
                                            zero to other zero.
2EB3    PF-TEST-2   BIT     0,B             The source pointer needs to be
                    JR      Z,2EB8,PF,ALL-9 incremented on every second
                    INC     HL              passage through the loop, when
                                            B is odd.
2EB8    PF-ALL-9    DJNZ    2EA1,PF-DIGITS  Jump back for all 9 digits.
                    LD      A,(mem-5-1st)   Get counter: were there 9 digits
                    SUB     +09             excluding leading zeros?
                    JR      C,2ECB,PF-MORE  If not, jump to get more digits.
                    DEC     (mem-5-1st)     Prepare to round: reduce count
                                            to 8.
                    LD      A,+04           Compare 9th digit, byte 4 of
                    CP      (mem-4-4th)     mem-4, with 4 to set carry for
                                            rounding up.
                    JR      2F0C,PF-ROUND   Jump forward to round up.
2ECB    PF-MORE     RST     0028,FP-CALC    Use the calculator again.
                    DEFB    +02,delete      - (i is now deleted).
                    DEFB    +E2,get-mem-2   f
                    DEFB    +38,end-calc    f
```

vi. The fractional part of x is now stored in the print buffer.

```
2ECF    PF-FRACTN   EX      DE,HL           DE now points to f.
                    CALL    2FBA,FETCH-TWO  The mantissa of f is now in
                                            D',E',D,E.
                    EXX                     Get the exchange registers.
                    LD      A,+80           The exponent of f is reduced to
                    SUB     L               zero, by shifting the bits of f 80
                    LD      L,+00           hex - e places right, where L'
                                            contained e.
                    SET     7,D             True numerical bit to bit 7 of
                                            D'.
                    EXX                     Restore the main registers.
                    CALL    2FDD,SHIFT-FP   Now make the shift.
2EDF    PF-FRN-LP   LP      A,(mem-5-1st)   Get the digit count.
                    CP      +08             Are there already 8 digits?
                    JR      C,2EEC,PR-FR-DGT If not, jump forward.
                    EXX                     If 8 digits, just use f to round i
                    RL      D               up, rotating D' left to set the
                                            carry.
                    EXX                     Restore main registers and jump
                    JR      2F0C,PF-ROUND   forward to round up.
2EEC    PF-FR-DGT   LD      BC,+0200        Initial zero to C, count of 2 to B.
2EEF    PF-FR-EXX   LD      A,E             D'E'DE is multiplied by 10 in 2
                    CALL    2F8B,CA=10*A+C  stages, first DE then D'E', each
                    LD      E,A             byte by byte in 2 steps, and the
                    LD      A,D             integer part of the result is
                    CALL    2F8B,CA=10*A+C  obtained in C to be passed into
                    LD      D,A             the print buffer.
                    PUSH    BC              The count and the result
                    EXX                     alternate between BC and B'C'.
                    POP     BC
                    DJNZ    2EEF,PF-FR-EXX  Look back once through the
                                            exchange registers.
                    LD      HL,+5CA1        The start - 1st byte of mem-3.
                    LD      A,C             Result to A for storing.
                    LD      C,(mem-5-1st)   Count of digits so far in number
                                            to C.
                    ADD     HL,BC           Address the first empty byte.
                    LD      (HL),A          Store the next digit.
```

```
                INC     (mem-5-1st)         Step up the count of digits.
                JR      2EDF,PF-FRN-LP      Loop back until there are 8
                                            digits.
```

vii. The digits stored in the print buffer are rounded to a maximum of 8 digits for printing.

```
2F0C  PF-ROUND  PUSH    AF                  Save the carry flag for the
                                            rounding.
                LD      HL,+5CA1            Base address of number: mem-3,
                                            byte 1.
                LD      C,(mem-5-1st)       Offset (number of digits in
                LD      B,+00               number) to BC.
                ADD     HL,BC               Address the last byte of the
                                            number.
                LD      B,C                 Copy C to B as the counter.
                POP     AF                  Restore the carry flag.
2F18  PF-RND-LP DEC     HL                  This is the last byte of the
                                            number.
                LD      A,(HL)              Get the byte into A.
                ADC     A,+00               Add in the carry i.e. round
                                            up.
                LD      (HL),A              Store the rounded byte in the
                                            buffer.
                AND     A                   If the byte is 0 or 10, B will be
                JR      Z,2F25,PF-R-BACK    decremented and the final zero
                CP      +0A                 (or the 10) will not be counted
                                            for printing.
                CCF                         Reset the carry for a valid digit.
                JR      NC,2F2D,PF-COUNT    Jump if carry reset.
2F25  PF-R-BACK DJNZ    2F18,PF-RND-LP      Jump back for more rounding
                                            or more final zeros.
                LD      (HL),+01            There is overflow to the left;
                INC     B                   an extra 1 is needed here.
                INC     (mem-5-2nd)         It is also an extra digit before
                                            the decimal.
2F2D  PF-COUNT  LD      (mem-5-1st),B       B now sets the count of the
                                            digits to be printed (final zeros
                                            will not be printed).
                RST     0028,FP-CALC        f is to be deleted.

                DEFB    +02,delete          -
                DEFB    +38,end-calc        -
                EXX                         The calculator offset saved on
                POP     HL                  the stack is restored to H'L'.
                EXX
```

viii. The number can now be printed. First C will be set to hold the number of digits to be printed, not counting final zeros, while B will hold the number of digits required before the decimal.

```
                LD      BC,(mem-5-1st)      The counters are set.
                LD      HL,+5CA1            The start of the digits.
                LD      A,B                 If more than 9, or fewer than
                CP      +09                 minus 4, digits are required
                JR      C,2F46,PF-NOT-E     before the decimal, then E-format
                                            will be needed.
                CP      +FC                 Fewer than 4 means more than
                JR      C,2F6C,PF-E-FRMT    4 leading zeros after the decimal.
2F46  PF-NOT-E  AND     A                   Are there no digits before the
                CALL    Z,15EF,OUT-CODE     decimal? If so, print an initial
                                            zero.
```

The next entry point is also used to print the digits needed for E-format printing.

```
2F4A  PF-E-SBRN XOR     A                   Start by setting A to zero.
```

		SUB	B	Subtract B: minus will mean
		JR	M,2F52,PF-OUT-LP	there are digits before the decimal; jump forward to print them.
		LD	B,A	A is now required as a counter.
		JR	2F5E,PF-DC-OUT	Jump forward to print the decimal part.
2F52	PF-OUT-LP	LD	A,C	Copy the number of digits to be
		AND	A	printed to A. If A is 0, there are
		JR	Z,2F59,PF-OUT-DT	still final zeros to print (B is non-zero), so jump.
		LD	A,(HL)	Get a digit from the print buffer.
		INC	HL	Point to the next digit.
		DEC	C	Decrease the count by one.
2F59	PF-OUT-DT	CALL	15EF,OUT-CODE	Print the appropriate digit.
		DJNZ	2F52,PF-OUT-LP	Loop back until B is zero.
2F5E	PF-DC-OUT	LD	A,C	It is time to print the decimal,
		AND	A	unless C is now zero; in that
		RET	Z	case, return - finished.
		INC	B	Add 1 to B - include the decimal.
		LD	A,+2E	Put the code for '.' into A.
2F64	PF-DEC-0S	RST	0010,PRINT-A-1	Print the '.'.
		LD	A,+30	Enter the character code for '0'.
		DJNZ	2F64,PF-DEC-0S	Loop back to print all needed zeros.
		LD	B,C	Set the count for all remaining digits.
		JR	2F52,PF-OUT-LP	Jump back to print them.
2F6C	PF-E-FRMT	LD	D,B	The count of digits is copied to D.
		DEC	D	It is decremented to give the exponent.
		LD	B,+01	One digit is required before the decimal in E-format.
		CALL	2F4A,PF-E-SBRN	All the part of the number before the 'E' is now printed.
		LD	A,+45	Enter the character code for 'E'.
		RST	0010,PRINT-A-1	Print the 'E'.
		LD	C,D	Exponent to C now for printing.
		LD	A,C	And to A for testing.
		AND	A	Its sign is tested.
		JP	P,2F83,PF-E-POS	Jump if it is positive.
		NEG		Otherwise, negate it in A.
		LD	C,A	Then copy it back to C for printing.
		LD	A,+2D	Enter the character code for '-'.
		JR	2F85,PF-E-SIGN	Jump to print the sign.
2F83	PF-E-POS	LD	A,+2B	Enter the character code for '+'.
2F85	PF-E-SIGN	RST	0010,PRINT-A-1	Now print the sign: '+' or '-'.
		LD	B,+00	BC holds the exponent for printing.
		JP	1A1B,OUT-NUM	Jump back to print it and finish.

THE 'CA=10*A+C' SUBROUTINE'

This subroutine is called by the PRINT-FP subroutine to multiply each byte of D'E'DE by 10 and return the integer part of the result in the C register. On entry, the A register contains the byte to be multiplied by 10 and the C register contains the carry over from the previous byte. On return, the A register contains the resulting byte and the C register the carry forward to the next byte.

```
2F8B    CA=10*A+C   PUSH    DE          Save whichever DE pair is in use.
                    LD      L,A         Copy the multiplicand from A
                    LD      H,+00       to HL.
                    LD      E,L         Copy it to DE too.
                    LD      D,H
                    ADD     HL,HL       Double HL.
                    ADD     HL,HL       Double it again.
                    ADD     HL,DE       Add in DE to give HL=5*A.
                    ADD     HL,HL       Double again: now HL=10*A.
                    LD      E,C         Copy C to DE (D is zero) for
                                        addition.
                    ADD     HL,DE       Now HL=10*A+C.
                    LD      C,H         H is copied to C.
                    LD      A,L         L is copied to A, completing
                                        the task.
                    POP     DE          The DE register pair is restored.
                    RET                 Finished.
```

THE 'PREPARE TO ADD' SUBROUTINE.

This subroutine is the first of four subroutines that are used by the main arithmetic operation routines - SUBTRACTION, ADDITION, MULTIPLICATION and DIVISION.
This particular subroutine prepares a floating-point number for addition, mainly by replacing the sign bit with a true numerical bit 1, and negating the number (two's complement) if it is negative. The exponent is returned in the A register and the first byte is set to Hex.00 for a positive number and Hex.FF for a negative number.

```
2F9B    PREP-ADD    LD      A,(HL)      Transfer the exponent to A.
                    LD      (HL),+00    Presume a positive number.
                    AND     A           If the number is zero then the
                    RET     Z           preparation is already finished.
                    INC     HL          Now point to the sign byte.
                    BIT     7,(HL)      Set the zero flag for positive
                                        number.
                    SET     7,(HL)      Restore the true numeric bit.
                    DEC     HL          Point to the first byte again.
                    RET     Z           Positive numbers have been
                                        prepared, but negative numbers
                                        need to be twos complemented.
                    PUSH    BC          Save any earlier exponent.
                    LD      BC,+0005    There are 5 bytes to be handled.
                    ADD     HL,BC       Point one-past the last byte.
                    LD      B,C         Transfer the '5' to B.
                    LD      C,A         Save the exponent in C.
                    SCF                 Set carry flag for negation.
2FAF    NEG-BYTE    DEC     HL          Point to each byte in turn.
                    LD      A,(HL)      Get each byte.
                    CPL                 One's complement the byte.
                    ADC     A,+00       Add in carry for negation.
                    LD      (HL),A      Restore the byte.
                    DJNZ    2FAF,NEG-BYTE  Loop the '5' times.
                    LD      A,C         Restore the exponent to A.
                    POP     BC          Restore any earlier exponent.
                    RET                 Finished.
```

THE 'FETCH TWO NUMBERS' SUBROUTINE

This subroutine is called by ADDITION, MULTIPLICATION and DIVISION to get two numbers from the calculator stack and put them into the register, including the exchange registers.
On entry to the subroutine the HL register pair points to the first byte of the first number and the DE register pair points to the first byte of the second number.
When the subroutine is called from MULTIPLICATION or DIVISION the sign of the result is saved in the second byte of the first number.

```
2FBA    FETCH-TWO   PUSH    HL          HL is preserved.
                    PUSH    AF          AF is preserved.

Call the five bytes of the first number     - M1, M2, M3, M4 & M5.
and the second number  - N1, N2, N3, N4 & N5.

                    LD      C,(HL)      M1 to C.
                    INC     HL          Next.
                    LD      B,(HL)      M2 to B.
                    LD      (HL),A      Copy the sign of the result to
                                        (HL).
                    INC     HL          Next.
                    LD      A,C         M1 to A.
                    LD      C,(HL)      M3 to C.
                    PUSH    BC          Save M2 & M3 on the machine
                                        stack.
                    INC     HL          Next.
                    LD      C,(HL)      M4 to C.
                    INC     HL          Next.
                    LD      B,(HL)      M5 to B.
                    EX      DE,HL       HL now points to N1.
                    LD      D,A         M1 to D.
                    LD      E,(HL)      N1 to E.
                    PUSH    DE          Save M1 & N1 on the machine
                                        stack.
                    INC     HL          Next.
                    LD      D,(HL)      N2 to D.
                    INC     HL          Next.
                    LD      E,(HL)      N3 to E.
                    PUSH    DE          Save N2 &N3 on the machine
                                        stack.
                    EXX                 Get the exchange registers.
                    POP     DE          N2 to D' & N3 to E'.
                    POP     HL          M1 to H' & N1 to L'.
                    POP     BC          M2 to B' & M3 to C'.
                    EXX                 Get the original set of registers.
                    INC     HL          Next.
                    LD      D,(HL)      N4 to D.
                    INC     HL          Next.
                    LD      E,(HL)      N5 to E.
                    POP     AF          Restore the original AF.
                    POP     HL          Restore the original HL.
                    RET                 Finished.

Summary:            M1 - M5 are in H', B', C', C, B.
                    N1 - N5 are in: L', D', E', D, E.
                    HL points to the first byte of the first number.
```

THE 'SHIFT ADDEND' SUBROUTINE

This subroutine shifts a floating-point number up to 32 decimal, Hex.20, places right to line it up properly for addition. The number with the smaller exponent has been put in the addend position before this subroutine is called. Any overflow to the right, into the carry, is added back into the number. If the exponent difference is greater than 32 decimal, or the carry ripples right back to the beginning of the number then the number is set to zero so that the addition will not alter the other number (the augend).

```
2FDD    SHIFT-FP    AND     A           If the exponent difference is
                    RET     Z           zero, the subroutine returns at
                    CP      +21         once. If the difference is greater
                    JR      NC,2FF9,ADDEND-0  than Hex.20, jump forward.
                    PUSH    BC          Save BC briefly.
                    LD      B,A         Transfer the exponent difference
                                        to B to count the shifts right.
2FE5    ONE-SHIFT   EXX                 Arithmetic shift right for L',
                    SRA     L           preserving the sign marker bits.
```

```
                    RR      D               Rotate right with carry D', E',
                    RR      E               D & E.
                    EXX                     Thereby shifting the whole five
                    RR      D               bytes of the number to the right
                    RR      E               as many times as B counts.
                    DJNZ    2FE5,ONE-SHIFT  Loop back until B reaches zero.
                    POP     BC              Restore the original BC.
                    RET     NC              Done if no carry to retrieve.
                    CALL    3004,ADD-BACK   Retrieve carry.
                    RET     NZ              Return unless the carry rippled
                                            right back. (In this case there is
                                            nothing to add).
2FF9  ADDEND-0      EXX                     Fetch L', D' & E'.
                    XOR     A               Clear the A register.
2FFB  ZEROS-4/5     LD      L,+00           Set the addend to zero in D',E',
                    LD      D,A             D & E, together with its marker
                    LD      E,L             byte (sign indicator) L', which
                    EXX                     was Hex.00 for a positive
                    LD      DE,+0000        number and Hex.FF for a
                                            negative number. ZEROS-4/5
                                            produces only 4 zero bytes
                                            when called for near underflow
                                            at 3160.
                    RET                     Finished.
```

THE 'ADD-BACK' SUBROUTINE

This subroutine adds back into the number any carry which has overflowed to the right. In the extreme case, the carry ripples right back to the left of the number.
When this subroutine is called during addition, this ripple means that a mantissa of 0.5 was shifted a full 32 places right, and the addend will now be set to zero; when called from MULTIPLICATION, it means that the exponent must be incremented, and this may result in overflow.

```
3004  ADD-BACK      INC     E               Add carry to rightmost byte.
                    RET     NZ              Return if no overflow to left.
                    INC     D               Continue to the next byte.
                    RET     NZ              Return if no overflow to left.
                    EXX                     Get the next byte.
                    INC     E               Increment it too.
                    JR      NZ,300D,ALL-ADDED Jump if no overflow.
                    INC     D               Increment the last byte.
300D  ALL-ADDED     EXX                     Restore the original
                                            registers.
                    RET                     Finished.
```

THE 'SUBTRACTION' OPERATION

(Offset 03 - see CALCULATE below: 'subtract')

This subroutine simply changes the sign of the subtrahend and carried on into ADDITION.
Note that HL points to the minuend and DE points to the subtrahend. (See ADDITION for more details.)

```
300F  SUBTRACT      EX      DE,HL           Exchange the pointers.
                    CALL    346E,NEGATE     Change the sign of the
                                            subtrahend.
                    EX      DE,HL           Exchange the pointers back and
                                            continue into ADDITION.
```

THE 'ADDITION' OPERATION

(Offset 0F - see CALCULATE below: 'addition')

The first of three major arithmetical subroutines, this subroutine carries out the floating-point addition of two numbers, each with a 4-byte mantissa and a 1-byte exponent. In these three subroutines, the two numbers at the top of the calculator stack are added/multiplied/divided to give one number at the top of the calculator stack, a 'last value'.

HL points to the second number from the top, the augend/multiplier/dividend. DE points to the number at the top of the calculator stack, the addend/multiplicand/divisor. Afterwards HL points to the resultant 'last value' whose address can also be considered to be STKEND - 5.
But the addition subroutine first tests whether the 2 numbers to be added are 'small integers'. If they are, it adds them quite simply in HL and BC, and puts the result directly on the stack. No twos complementing is needed before or after the addition, since such numbers are held on the stack in twos complement form, ready for addition.

3014	addition	LD	A,(DE)	Test whether the first bytes of
		OR	(HL)	both numbers are zero.
		JR	NZ,303E,FULL-ADDN	If not, jump for full addition.
		PUSH	DE	Save the pointer to the second number.
		INC	HL	Point to the second byte of the
		PUSH	HL	first number and save that pointer too.
		INC	HL	Point to the less significant byte.
		LD	E,(HL)	Fetch it in E.
		INC	HL	Point to the more significant byte.
		LD	D,(HL)	Fetch it in D.
		INC	HL	Move on to the second byte of
		INC	HL	the second number.
		INC	HL	
		LD	A,(HL)	Fetch it in A (this is the sign byte).
		INC	HL	Point to the less significant byte.
		LD	C,(HL)	Fetch it in C.
		INC	HL	Point to the more significant byte.
		LD	B,(HL)	Fetch is in B.
		POP	HL	Fetch the pointer to the sign
		EX	DE,HL	byte of the first number; put it in DE, and the number in HL.
		ADD	HL,BC	Perform the addition: result in HL.
		EX	DE,HL	Result to DE, sign byte to HL.
		ADC	A,(HL)	Add the sign bytes and the carry
		RRCA		into A; this will detect any overflow.
		ADC	A,+00	A non-zero A now indicates overflow.
		JR	NZ,303C,ADDN-OFLW	Jump to reset the pointers and to do full addition.
		SBC	A,A	Define the correct sign byte for the result.
3032		LD	(HL),A	Store it on the stack.
		INC	HL	Point to the next location.
		LD	(HL),E	Store the low byte of the result.
		INC	HL	Point to the next location.
		LD	(HL),D	Store the high byte of the result.
		DEC	HL	Move the pointer back to
		DEC	HL	address the first byte of the
		DEC	HL	result.
		POP	DE	Restore STKEND to DE.
		RET		Finished.

Note that the number -65536 decimal can arise here in the form 00 FF 00 00 00 as the result of the addition of two smaller negative integers, e.g. -65000 and -536. It is simply stacked in this form. This is a mistake. The Spectrum system cannot handle this number.

Most functions treat it as zero, and it is printed as -1E-38, obtained by treating is as 'minus zero' in an illegitimate format.
One possible remedy would be to test for this number at about byte 3032 and, if it is present, to make the second byte 80 hex and the first byte 91 hex, so producing the full five byte floating-point form of the number, i.e. 91 80 00 00 00, which causes no problems. See also the remarks in 'truncate' below, before byte 3225, and the Appendix.

303C	ADDN-OFLW	DEC	HL	Restore the pointer to the first number.
		POP	DE	Restore the pointer to the second number.
303E	FULL-ADDN	CALL	3293,RE-ST-TWO	Re-stack both numbers in full five byte floating-point form.

The full ADDITION subroutine first calls PREP-ADD for each number, then gets the two numbers from the calculator stack and puts the one with the smaller exponent into the addend position. It then calls SHIFT-FP to shift the addend up to 32 decimal places right to line it up for addition. The actual addition is done in a few bytes, a single shift is made for carry (overflow to the left) if needed, the result is twos complemented if negative, and any arithmetic overflow is reported; otherwise the subroutine jumps to TEST-NORM to normalise the result and return it to the stack with the correct sign bit inserted into the second byte.

		EXX		Exchange the registers.
		PUSH	HL	Save the next literal address.
		EXX		Exchange the registers.
		PUSH	DE	Save pointer to the addend.
		PUSH	HL	Save pointer to the augend.
		CALL	2F9B,PREP-ADD	Prepare the augend.
		LD	B,A	Save its exponent in B.
		EX	DE,HL	Exchange its pointers.
		CALL	2F9B,PREP-ADD	Prepare the addend.
		LD	C,A	Save its exponent in C.
		CP	B	If the first exponent is smaller,
		JR	NC,3055,SHIFT-LEN	keep the first number in the
		LD	A,B	addend position; otherwise
		LD	B,C	change the exponents and the
		EX	DE,HL	pointers back again.
3055	SHIFT-LEN	PUSH	AF	Save the larger exponent in A.
		SUB	B	The difference between the exponents is the length of the shift right.
		CALL	2FBA,FETCH-TWO	Get the two numbers from the stack.
		CALL	2FDD,SHIFT-FP	Shift the addend right.
		POP	AF	Restore the larger exponent.
		POP	HL	HL is to point to the result.
		LD	(HL),A	Store the exponent of the result.
		PUSH	HL	Save the pointer again.
		LD	L,B	M4 to H & M5 to L,
		LD	H,C	(see FETCH-TWO).
		ADD	HL,DE	Add the two right bytes.
		EXX		N2 to H' & N3 to L',
		EX	DE,HL	(see FETCH-TWO).
		ADC	HL,BC	Add left bytes with carry.
		EX	DE,HL	Result back in D'E'.
		LD	A,H	Add H', L' and the carry; the
		ADC	A,L	resulting mechanisms will ensure
		LD	L,A	that a single shift right is called
		RRA		if the sum of 2 positive numbers
		XOR	L	has overflowed left, or the sum
		EXX		of 2 negative numbers has not overflowed left.

```
                    EX      DE,HL           The result is now in DED'E.
                    POP     HL              Get the pointer to the
                                            exponent.
                    RRA                     The test for shift (H', L' were
                    JR      NC,307C,TEST-NEG Hex. 00 for positive numbers
                                            and Hex.FF for negative
                                            numbers).
                    LD      A,+01           A counts a single shift right.
                    CALL    2FDD,SHIFT-FP   The shift is called.
                    INC     (HL)            Add 1 to the exponent; this
                    JR      Z,309F,ADD-REP-6 may lead to arithmetic overflow.

307C  TEST-NEG      EXX                     Test for negative result: get
                    LD      A,L             sign bit of L' into A (this now
                    AND     +80             correctly indicates the sign of
                    EXX                     the result).
                    INC     HL              Store it in the second byte
                    LD      (HL),A          position of the result on
                    DEC     HL              the calculator stack.
                    JR      Z,30A5,GO-NC-MLT If it is zero, then do not
                                            twos complement the result.
                    LD      A,E             Get the first byte.
                    NEG                     Negate it.
                    CCF                     Complement the carry for
                    LD      E,A             continued negation, and store
                                            byte.
                    LD      A,D             Get the next byte.
                    CPL                     Ones complement it.
                    ADC     A,+00           Add in the carry for negation.
                    LD      D,A             Store the byte.
                    EXX                     Proceed to get next byte into
                    LD      A,E             the A register.
                    CPL                     Ones complement it.
                    ADC     A,+00           Add in the carry for negation.
                    LD      E,A             Store the byte.
                    LD      A,D             Get the last byte.
                    CPL                     Ones complement it.
                    ADC     A,+00           Add in the carry for negation.
                    JR      NC,30A3,END-COMPL Done if no carry.
                    RRA                     Else, get .5 into mantissa and
                    EXX                     add 1 to the exponent; this will
                    INC     (HL)            be needed when two negative
                                            numbers add to give an exact
                                            power of 2, and it may lead to
                                            arithmetic overflow.
309F  ADD-REP-6     JP      Z,31AD,REPORT-6 Give the error if required.
                    EXX
30A3  END-COMPL     LD      D,A             Store the last byte.
                    EXX
30A5  GO-NC-MLT     XOR     A               Clear the carry flag.
                    JP      3155,TEST-NORM  Exit via TEST-NORM.
```

THE 'HL=HL*DE' SUBROUTINE

This subroutine is called by 'GET-HL*DE' and by 'MULTIPLICATION' to perform the 16-bit multiplication as stated. Any overflow of the 16 bits available is dealt with on return from the subroutine.

```
30A9  HL=HL*DE      PUSH    BC              BC is saved.
                    LD      B,+10           It is to be a 16 bit multipli-
                                            cation.
                    LD      A,H             A holds the high byte.
                    LD      C,L             C holds the low byte.
                    LD      HL,+0000        Initialise the result to zero.
30B1  HL-LOOP       ADD     HL,HL           Double the result.
```

```
                    JR      C,30BE,HL-END       Jump if overflow.
                    RL      C                   Rotate bit 7 of C into the carry.
                    RLA                         Rotate the carry bit into bit 0
                                                and bit 7 into the carry flag.
                    JR      NC,30BC,HL-AGAIN    Jump if the carry flag is reset.
                    ADD     HL,DE               Otherwise add DE in once.
                    JR      C,30BE,HL-END       Jump if overflow.
30BC    HL-AGAIN    DJNZ    30B1,HL-LOOP        Until 16 passes have been made.
30BE    HL-END      POP     BC                  Restore BC.
                    RET                         Finished.
```

THE 'PREPARE TO MULTIPLY OR DIVIDE' SUBROUTINE

This subroutine prepares a floating-point number for multiplication or division, returning with carry set if the number is zero, getting the sign of the result into the A register, and replacing the sign bit in the number by the true numeric bit, 1.

```
30C0    PREP-M/D    CALL    34E9,TEST-ZERO      If the number is zero, return
                    RET     C                   with the carry flag set.
                    INC     HL                  Point to the sign byte.
                    XOR     (HL)                Get sign for result into A (like
                                                signs give plus, unlike give
                                                minus); also reset the carry flag.
                    SET     7,(HL)              Set the true numeric bit.
                    DEC     HL                  Point to the exponent again.
                    RET                         Return with carry flag reset.
```

THE 'MULTIPLICATION' OPERATION

(Offset 04 - see CALCULATE below: 'multiply')

This subroutine first tests whether the two numbers to be multiplied are 'small integers'. If they are, it uses INT-FETCH to get them from the stack, HL=HL*DE to multiply them and INT-STORE to return the result to the stack. Any overflow of this 'short multiplication' (i.e. if the result is not itself a 'small integer') causes a jump to multiplication in full five byte floating-point form (see below).

```
30CA    multiply    LD      A,(DE)              Test whether the first bytes of
                    OR      (HL)                both numbers are zero.
                    JR      NZ,30F0,MULT-LONG   If not, jump for 'long' multi-
                                                plication.
                    PUSH    DE                  Save the pointers: to the second
                                                number.
                    PUSH    HL                  And to the first number.
                    PUSH    DE                  And to the second number yet
                                                again.
                    CALL    2D7F,INT-FETCH      Fetch sign in C, number in DE.
                    EX      DE,HL               Number to HL now.
                    EX      (SP),HL             Number to stack, second
                                                pointer to HL.
                    LD      B,C                 Save first sign in B.
                    CALL    2D7F,INT-FETCH      Fetch second sign in C, number
                                                in DE.
                    LD      A,B                 Form sign of result in A: like
                    XOR     C                   signs give plus (00), unlike give
                                                minus (FF).
                    LD      C,A                 Store sign of result in C.
                    POP     HL                  Restore the first number to HL.
                    CALL    30A9,HL=HL*DE       Perform the actual multipli-
                                                cation.
                    EX      DE,HL               Store the result in DE.
                    POP     HL                  Restore the pointer to the first
                                                number.
                    JR      C,30EF,MULT-OFLW    Jump on overflow to 'full'
                                                multiplication.
30E5                LD      A,D                 These 5 bytes ensure that
```

```
                    OR      E               00 FF 00 00 00 is replaced by
                    JR      NZ,30EA,MULT-RSLT zero; that they should not be
                    LD      C,A             needed if this number were
                                            excluded from the system (see
                                            after 303B) above).
30EA    MULT-RSLT   CALL    2D8E,INT-STORE  Now store the result on the
                                            stack.
                    POP     DE              Restore STKEND to DE.
                    RET                     Finished.
30EF    MULT-OFLW   POP     DE              Restore the pointer to the
                                            second number.
30F0    MULT-LONG   CALL    3293,RE-ST-TWO  Re-stack both numbers in full
                                            five byte floating-point form.
```

The full MULTIPLICATION subroutine prepares the first number for multiplication by calling PREP-M/D, returning if it is zero; otherwise the second number is prepared by again calling PREP-M/D, and if it is zero the subroutine goes to set the result to zero. Next it fetches the two numbers from the calculator stack and multiplies their mantissas in the usual way, rotating the first number (treated as the multiplier) right and adding in the second number (the multiplicand) to the result whenever the multiplier bit is set. The exponents are then added together and checks are made for overflow and for underflow (giving the result zero). Finally, the result is normalised and returned to the calculator stack with the correct sign bit in the second byte.

```
                    XOR     A               A is set to Hex.00 so that the
                                            sign of the first number will go
                                            into A.
                    CALL    30C0,PREP-M/D   Prepare the first number, and
                    RET     C               return if zero. (Result already
                                            zero.)
                    EXX                     Exchange the registers.
                    PUSH    HL              Save the next literal address.
                    EXX                     Exchange the registers.
                    PUSH    DE              Save the pointer to the multi-
                                            plicand.
                    EX      DE,HL           Exchange the pointers.
                    CALL    30C0,PREP-M/D   Prepare the 2nd number.
                    EX      DE,HL           Exchange the pointers again.
                    JR      C,315D,ZERO-RSLT Jump forward if 2nd number is
                                            zero.
                    PUSH    HL              Save the pointer to the result.
                    CALL    2FBA,FETCH-TWO  Get the two numbers from
                                            the stack.
                    LD      A,B             M5 to A (see FETCH-TWO).
                    AND     A               Prepare for a subtraction.
                    SBC     HL,HL           Initialise HL to zero for the
                                            result.
                    EXX                     Exchange the registers.
                    PUSH    HL              Save M1 & N1 (see
                                            FETCH-TWO).
                    SBC     HL,HL           Also initialise H'L' for the
                                            result.
                    EXX                     Exchange the registers.
                    LD      B,+21           B counts 33 decimal, Hex.21,
                                            shifts.
                    JR      3125,STRT-MLT   Jump forward into the loop.
```

Now enter the multiplier loop.

```
3114    MLT-LOOP    JR      NC,311B,NO-ADD  Jump forward to NO-ADD if no
                                            carry, i.e. the multiplier bit was
                                            reset.
                    ADD     HL,DE           Else, add the multiplicand in
                    EXX                     D'E'DE (see FETCH-TWO) into
                    ADC     HL,DE           the result being built up on
```

```
                EXX                             H'L'HL.
311B  NO-ADD    EXX                             Whether multiplicand was added
                RR      H                       or not, shift result right in
                RR      L                       H'L'HL, i.e. the shift is done by
                EXX                             rotating each byte with carry, so
                RR      H                       that any bit that drops into the
                RR      L                       carry is picked up by the next
                                                byte, and the shift continued
                                                into B'C'CA.
3125  STRT-MLT  EXX                             Shift right the multiplier in
                RR      B                       B'C'CA (see FETCH-TWO &
                                                above).
                RR      C                       A final bit dropping into the
                EXX                             carry will trigger another add of
                RR      C                       the multiplicand to the result.
                RRA
                DJNZ    3114,MLT-LOOP           Loop 33 times to get all the bits.
                EX      DE,HL                   Move the result from:
                EXX
                EX      DE,HL                   H'L'HL to D'E'DE.
                EXX
```

Now add the exponents together.

```
                POP     BC                      Restore the exponents - M1
                                                & N1.
                POP     HL                      Restore the pointer to the
                                                exponent byte.
                LD      A,B                     Get the sum of the two
                ADD     A,C                     exponent bytes in A, and the
                                                correct carry.
                JR      NZ,313B,MAKE-EXPT       If the sum equals zero then clear
                AND     A                       the carry; else leave it
                                                unchanged.
313B  MAKE-EXPT DEC     A                       Prepare to increase the
                CCF                             exponent by Hex.80.
```

The rest of the subroutine is common to both MULTIPLICATION and DIVISION.

```
313D  DIVN-EXPT RLA                             These few bytes very cleverly
                CCF                             make the correct exponent
                                                byte.
                RRA                             Rotating left then right gets the
                                                exponent byte (true exponent
                                                plus Hex.80) into A.
                JP      P,3146,OFLW1-CLR        If the sign flag is reset, no report
                                                of arithmetic overflow needed.
                JR      NC,31AD,REPORT-6        Report the overflow if carry
                                                reset.
                AND     A                       Clear the carry now.
3146  OFLW1-CLR INC     A                       The exponent byte is now com-
                JR      NZ,3151,OFLW2-CLR       plete; but if A is zero a further
                JR      C,3151,OFLW2-CLR        check for overflow is needed.
                EXX                             If there is no carry set and the
                BIT     7,D                     result is already in normal form
                EXX                             (bit 7 of D' set) then there is
                JR      NZ,31AD,REPORT-6        overflow to report; but if bit 7
                                                of D' is reset, the result in just in
                                                range, i.e. just under 2**127.
3151  OFLW2-CLR LD      (HL),A                  Store the exponent byte, at last.
                EXX                             Pass the fifth result byte to A
                LD      A,B                     for the normalisation sequence,
                EXX                             i.e. the overflow from L into B'.
```

The remainder of the subroutine deals with normalisation and is common to all the arithmetic routines.

```
3155  TEST-NORM   JR    NC,316C,NORMALISE  If no carry then normalise now.
                  LD    A,(HL)             Else, deal with underflow (zero
                  AND   A                  result) or near underflow
3159  NEAR-ZERO   LD    A,+80              (result 2**-128):
                  JR    Z,315E,SKIP-ZERO   return exponent to A, test if A
315D  ZERO-RSLT   XOR   A                  is zero (case 2**-128) and if so
315E  SKIP-ZERO   EXX                      produce 2**-128 if number is
                  AND   D                  normal; otherwise produce zero.
                  CALL  2FFB,ZEROS-4/5     The exponent must then be set
                  RLCA                     to zero (for zero) or 1 (for
                                           2**-128).
                  LD    (HL),A             Restore the exponent byte.
                  JR    C,3195,OFLOW-CLR   Jump if case 2**-128.
                  INC   HL                 Otherwise, put zero into second
                  LD    (HL),A             byte of result on the calculator
                  DEC   HL                 stack.
                  JR    3195,OFLOW-CLR     Jump forward to transfer the
                                           result.
```

The actual normalisation operation.

```
316C  NORMALISE   LD    B,+20              Normalise the result by up to 32
316E  SHIFT-ONE   EXX                      decimal, Hex.20, shifts left of
                  BIT   7,D                D'E'DE (with A adjoined) until
                  EXX                      bit 7 of D' is set. A holds zero
                  JR    NZ,3186,NORML-NOW  after addition so no precision is
                  RLCA                     gained or lost; A holds the fifth
                  RL    E                  byte from B' after multiplica-
                  RL    D                  tion or division; but as only
                  EXX                      about 32 bits can be correct, no
                  RL    E                  precision is lost. Note that A is
                  RL    D                  rotated circularly, with branch
                  EXX                      at carry .... eventually a random
                                           process.
                  DEC   (HL)               The exponent is decremented
                                           on each shift.
                  JR    Z,3159,NEAR-ZERO   If the exponent becomes zero,
                                           then number from 2**-129 are
                                           rounded up to 2**-128.
                  DJNZ  316E,SHIFT-ONE     Loop back, up to 32 times.
                  JR    315D,ZERO-RSLT     If bit 7 never became 1 then the
                                           whole result is to be zero.
```

Finish the normalisation by considering the 'carry'.

```
3186  NORML-NOW   RLA                      After normalisation add back
                  JR    NC,3195,OFLW-CLR   any final carry that went into A.
                  CALL  3004,ADD-BACK      Jump forward if the carry does
                  JR    NZ,3195,OFLW-CLR   not ripple right back.
                  EXX                      If it should ripple right back
                  LD    D,+80              then set mantissa to 0.5 and
                  EXX                      increment the exponent.
                  INC   (HL)               This action may lead to arith-
                  JR    Z,31AD,REPORT-6    metic overflow (final case).
```

The final part of the subroutine involves passing the result to the bytes reserved for it on the calculator stack and resetting the pointers.

```
3195  OFLOW-CLR   PUSH  HL                 Save the result pointer.
                  INC   HL                 Point to the sign byte in the
                                           result.
                  EXX                      The result is moved from its
                  PUSH  DE                 present registers, D'E'DE, to
                  EXX                      BCDE; and then to ACDE.
```

```
                POP     BC
                LD      A,B             The sign bit is retrieved from
                RLA                     its temporary store and trans-
                RL      (HL)            ferred to its correct position of
                RRA                     bit 7 of the first byte of the
                                        mantissa.
                LD      (HL),A          The first byte is stored.
                INC     HL              Next.
                LD      (HL),C          The second byte is stored.
                INC     HL              Next.
                LD      (HL),D          The third byte is stored.
                INC     HL              Next.
                LD      (HL),E          The fourth byte is stored.
                POP     HL              Restore the pointer to the
                                        result.
                POP     DE              Restore the pointer to second
                                        number.
                EXX                     Exchange the register.
                POP     HL              Restore the next literal address.
                EXX                     Exchange the registers.
                RET                     Finished.
```

Report 6 - Arithmetic overflow

```
31AD  REPORT-6  RST     0008,ERROR-1    Call the error handling
                DEFB    +05             routine.
```

THE 'DIVISION' OPERATION

(Offset 05 - see CALCULATE below: 'division')

This subroutine first prepared the divisor by calling PREP-M/D, reporting arithmetic overflow if it is zero; then it prepares the dividend again calling PREP-M/D, returning if it is zero. Next fetches the two numbers from the calculator stack and divides their mantissa by means of the usual restoring division, trial subtracting the divisor from the dividend and restoring if there is carry, otherwise adding 1 to the quotient. The maximum precision is obtained for a 4-byte division, and after subtracting the exponents the subroutine exits by joining the later part of MULTIPLICATION.

```
31AF  division  CALL    3293,RE-ST-TWO  Use full floating-point forms.
                EX      DE,HL           Exchange the pointers.
                XOR     A               A is set to Hex.00, so that the
                                        sign of the first number will go
                                        into A.
                CALL    30C0,PREP-M/D   Prepare the divisor and give the
                JR      C,31AD,REPORT-6 report for arithmetic overflow if
                                        it is zero.
                EX      DE,HL           Exchange the pointers.
                CALL    30C0,PREP-M/D   Prepare the dividend and return
                RET     C               if it is zero (result already zero).
                EXX                     Exchange the pointers.
                PUSH    HL              Save the next literal address.
                EXX                     Exchange the registers.
                PUSH    DE              Save pointer to divisor.
                PUSH    HL              Save pointer to dividend.
                CALL    2FBA,FETCH-TWO  Get the two numbers from the
                                        stack.
                EXX                     Exchange the registers.
                PUSH    HL              Save M1 & N1 on the machine
                                        stack.
                LD      H,B             Copy the four bytes of the
                LD      L,C             dividend from registers B'C'CB
                EXX                     (i.e. M2, M3, M4 & M5; see
                LD      H,C             FETCH-TWO) to the registers
                                        H'L'HL.
                LD      L,B
```

```
                XOR     A               Clear A and reset the carry flag.
                LD      B,+DF           B will count upwards from -33
                                        to -1, twos complement,
                                        Hex. DF to FF, looping on
                                        minus and will jump again on
                                        zero for extra precision.
                JR      31E2,DIV-START  Jump forward into the division
                                        loop for the first trial
                                        subtraction.
```

Now enter the division loop.

```
31D2  DIV-LOOP  RLA                     Shift the result left into B'C'CA,
                RL      C               shifting out the bits already
                EXX                     there, picking up 1 from the
                RL      C               carry whenever it is set, and
                RL      B               rotating left each byte with
                EXX                     carry to achieve the 32 bit
                                        shift.
31DB  DIV-34TH  ADD     HL,HL           Move what remains of the
                EXX                     dividend left in H'L'HL before
                ADC     HL,HL           the next trial subtraction; if a
                EXX                     bit drops into the carry, force
                                        no restore and a bit for the
                                        quotient, thus retrieving the lost
                JR      C,31F2,SUBN-ONLY bit and allowing a full 32-bit
                                        divisor.
31E2  DIV-START SBC     HL,DE           Trial subtract divisor in D'E'DE
                EXX                     from rest of dividend in H'L'HL;
                SBC     HL,DE           there is no initial carry (see
                EXX                     previous step).
                JR      NC,31F9,NO-RSTORE Jump forward if there is no
                                        carry.
                ADD     HL,DE           Otherwise restore, i.e. add back
                EXX                     the divisor. Then clear the carry
                ADC     HL,DE           so that there will be no bit for
                EXX                     the quotient (the divisor 'did
                AND     A               not go').
                JR      31FA,COUNT-ONE  Jump forward to the counter.
31F2  SUBN-ONLY AND     A               Just subtract with no restore
                SBC     HL,DE           and go on to set the carry flag
                EXX                     because the lost bit of the divi-
                SBC     HL,DE           dend is to be retrieved and used
                EXX                     for the quotient.
31F9  NO-RSTORE SCF     One for the quotient in B'C'CA.
31FA  COUNT-ONE INC     B               Step the loop count up by one.
                JP      M,31D2,DIV-LOOP Loop 32 times for all bits.
                PUSH    AF              Save any 33rd bit for extra
                                        precision (the present carry).
                JR      Z,31E2,DIV-START Trial subtract yet again for any
                                        34th bit; the PUSH AF above
                                        saves this bit too.
```

Note: This jump is made to the wrong place. No 34th bit will ever be obtained without first shifting the dividend. Hence important results like 1/10 and 1/1000 are not rounded up as they should be. Rounding up never occurs when it depends on the 34th bit. The jump should have been to 31DB DIV-34TH above: i.e. byte 3200 hex in the ROM should read DA hex (128 decimal) instead of E1 hex (225 decimal).

```
                LD      E,A             Now move the four bytes that
                LD      D,C             form the mantissa bytes of the
                EXX                     result from B'C'CA to D'E'DE.
                LD      E,C
                LD      D,B
                POP     AF              Then put the 34th and 33rd bits
```

		RR	B	into 'B' to be picked up on
		POP	AF	normalisation.
		RR	B	
		EXX		
		POP	BC	Restore the exponent bytes, M1 & N1.
		POP	HL	Restore the pointer to the result.
		LD	A,B	Get the difference between the
		SUB	C	two exponent bytes into A and set the carry flag if required.
		JP	313D,DIVN-EXPT	Exit via DIVN-EXPT.

THE 'INTEGER TRUNCATION TOWARDS ZERO' SUBROUTINE

(Offset 3A - see CALCULATE below: 'truncate')

This subroutine (say I(x)) returns the result of integer truncation of x, the 'last value', towards zero. Thus I(2.4) is 2 and I(-2.4) is -2. The subroutine returns at once if x is in the form of a 'short integer'. It returns zero if the exponent byte of x if less than 81 hex (ABS x is less than 1). If I(x) is a 'short integer' the subroutine returns it in that form. It returns x if the exponent byte is A0 hex or greater (x has no significant non-integral part). Otherwise the correct number of bytes of x are set to zero and, if needed, one more byte is split with a mask.

3214	truncate	LD	A,(HL)	Get the exponent byte of X into A.
		AND	A	If A is zero, return since x is
		RET	Z	already a small integer.
		CP	+81	Compare e, the exponent, to 81 hex.
		JR	NC,3221,T-GR-ZERO	Jump if e is greater than 80 hex.
		LD	(HL),+00	Else, set the exponent to zero;
		LD	A,+20	enter 32 decimal, 20 hex, into A
		JR	3272,NIL-BYTES	and jump forward to NIL-BYTES to make all the bits of x be zero.
3221	T-GR-ZERO	CP	+91	Compare e to 91 hex, 145 decimal.
3223		JR	NZ,323F,T-SMALL	Jump if e not 91 hex.

The next 26 bytes seem designed to test whether x is in fact -65536 decimal, i.e. 91 80 00 00 00, and if it is, to set it to 00 FF 00 00 00. This is a mistake. As already stated at byte 303B above, the Spectrum system cannot handle this number. The result here is simply to make INT (-65536) return the value -1. This is a pity, since the number would have been perfectly all right if left alone. The remedy would seem to be simply to omit the 28 bytes from 3223 above to 323E inclusive from the program.

3225		INC	HL	HL is pointed at the fourth byte
		INC	HL	of x, where the 17 bits of the
		INC	HL	integer part of x end after the first bit.
		LD	A,+80	The first bit is obtained in A.
		AND	(HL)	using 80 hex as a mask.
		DEC	HL	That bit and the previous 8 bits
		OR	(HL)	are tested together for zero.
		DEC	HL	HL is pointed at the second byte of x.
		JR	NZ,3233,T-FIRST	If already non-zero, the test can end.
		LD	A,+80	Otherwise, the test for -65536 is
		XOR	(HL)	now completed: 91 80 00 00 00 will leave the zero flag set now.
3233	T-FIRST	DEC	HL	HL is pointed at the first byte of x.
		JR	NZ,326C,T-EXPNENT	If zero reset, the jump is made.
		LD	(HL),A	The first byte is set to zero.
		INC	HL	HL points to the second byte.

```
                LD      (HL),+FF        The second byte is set to FF.
                DEC     HL              HL again points to the first
                                        byte.
                LD      A,+18           The last 24 bits are to be zero.
                JR      3272,NIL-BYTES  The jump to NIL-BYTES
                                        completes the number 00 FF
                                        00 00 00.
```

If the exponent byte of x is between 81 and 90 hex (129 and 144 decimal) inclusive, I(x) is a 'small integer', and will be compressed into one or two bytes. But first a test is made to see whether x is, after all, large.

```
323F  T-SMALL   JR      NC,326D,X-LARGE Jump with exponent byte 92
                                        or more (it would be better to
                                        jump with 91 too).
                PUSH    DE              Save STKEND in DE.
                CPL                     Range 129 <= A <= 144 becomes
                                        126 >= A >= 111.
                ADD     A,+91           Range is now 15 dec >= A >= 0.
                INC     HL              Point HL at second byte.
                LD      D,(HL)          Second byte to D.
                INC     HL              Point HL at third byte.
                LD      E,(HL)          Third byte to E.
                DEC     HL              Point HL at first byte again.
                DEC     HL
                LD      C,+00           Assume a positive number.
                BIT     7,D             Now test for negative (bit 7
                                        set).
                JR      Z,3252,T-NUMERIC Jump if positive after all.
                DEC     C               Change the sign.
3252  T-NUMERIC SET     7,D             Insert true numeric bit, 1, in D.
                LD      B,+08           Now test whether A >= 8 (one
                SUB     B               byte only) or two bytes needed.
                ADD     A,B             Leave A unchanged.
                JR      C,325E,T-TEST   Jump if two bytes needed.
                LD      E,D             Put the one byte into E.
                LD      D,+00           And set D to zero.
                SUB     B               Now 1 <= A <= 7 to count the
                                        shifts needed.
325E  T-TEST    JR      Z,3267,T-STORE  Jump if no shift needed.
                LD      B,A             B will count the shifts.
3261  T-SHIFT   SRL     D               Shift D and E right B times to
                RR      E               produce the correct number.
                DJNZ    3261,T-SHIFT    Loop until B is zero.
3267  T-STORE   CALL    2D8E,INT-STORE  Store the result on the stack.
                POP     DE              Restore STKEND to DE.
                RET                     Finished.
```

Large values of x remains to be considered.

```
326C  T-EXPNENT LD      A,(HL)          Get the exponent byte of x into
                                        A.
326D  X-LARGE   SUB     +A0             Subtract 160 decimal, A0 hex,
                                        from e.
                RET     P               Return on plus - x has no
                                        significant non-integral part. (If
                                        the true exponent were reduced
                                        to zero, the 'binary point'
                                        would come at or after the end
                                        of the four bytes of the man-
                                        tissa).
                NEG                     Else, negate the remainder; this
                                        gives the number of bits to
                                        become zero (the number of
                                        bits after the 'binary point').
```

Now the bits of the mantissa can be cleared.

```
3272  NIL-BYTES   PUSH  DE                 Save the current value of DE
                                           (STKEND).
                  EX    DE,HL              Make HL point one past the fifth
                                           byte.
                  DEC   HL                 HL now points to the fifth byte
                                           of x.
                  LD    B,A                Get the number of bits to be set
                  SRL   B                  to zero in B and divide it by B
                  SRL   B                  to give the number of whole
                  SRL   B                  bytes implied.
                  JR    Z,3283,BITS-ZERO   Jump forward if the result is
                                           zero.
327E  BYTE-ZERO   LD    (HL),+00           Else, set the bytes to zero;
                  DEC   HL                 B counts them.
                  DJNZ  327E,BYTE-ZERO
3283  BITS-ZERO   AND   +07                Get A (mod 8); this is the num-
                                           ber of bits still to be set to zero.
                  JR    Z,3290,IX-END      Jump to the end if nothing
                                           more to do.
                  LD    B,A                B will count the bits now.
                  LD    A,+FF              Prepare the mask.
328A  LESS-MASK   SLA   A                  With each loop a zero enters the
                  DJNZ  328A,LESS-MASK     mask from the right and thereby
                                           a mask of the correct length is
                                           produced.
                  AND   (HL)               The unwanted bits of (HL) are
                  LD    (HL),A             lost as the masking is performed.
3290  IX-END      EX    DE,HL              Return the pointer to HL.
                  POP   DE                 Return STKEND to DE.
                  RET                      Finished.
```

THE 'RE-STACK TWO' SUBROUTINE

This subroutine is called to re-stack two ‘small integers’ in full five byte floating-point form for the binary operations of addition, multiplication and division. It does so by calling the following subroutine twice.

```
3293  RE-ST-TWO   CALL  3269,RESTK-SUB   Call the subroutine, and then
                                           continue into it for the second
                                           call.
3296  RESTK-SUB   EX    DE,HL            Exchange the pointers at each
                                           call.
```

THE 'RE-STACK TWO' SUBROUTINE

(Offset 3D - see CALCULATE below: 're-stack')
This subroutine is called to re-stack one number (which could be a 'small integer') in full five byte floating-point form. It is used for a single number by ARCTAN and also, through the calculator offset, by EXP, LN and 'get-argt'.

```
3297  RE-STACK    LD    A,(HL)             If the first byte is not zero,
                  AND   A                  return - the number cannot be
                  RET   NZ                 a 'small integer'.
                  PUSH  DE                 Save the 'other' pointer in DE.
                  CALL  2D7F,INT-FETCH     Fetch the sign in C and the
                                           number in DE.
                  XOR   A                  Clear the A register.
                  INC   HL                 Point to the fifth location.
                  LD    (HL),A             Set the fifth byte to zero.
                  DEC   HL                 Point to the fourth location.
                  LD    (HL),A             Set the fourth byte to zero:
                                           bytes 2 and 3 will hold the man-
                                           tissa.
```

```
                    LD      B,+91           Set B to 145 dec for the
                                            exponent i.e. for up to 16 bits
                                            in the integer.
                    LD      A,D             Test whether D is zero so that
                    AND     A               at most 8 bits would be needed.
                    JR      NZ,32B1,RS-NRMLSE Jump if more than 8 bits needed.
                    OR      E               Now test E too.
                    LD      B,D             Save the zero in B (it will give
                                            zero exponent if E too is zero).
                    JR      Z,32BD,RS-STORE Jump if E is indeed zero.
                    LD      D,E             Move E to D (D was zero, E
                                            not).
                    LD      E,B             Set E to zero now.
                    LD      B,+89           Set B to 137 dec for the
                                            exponent - no more than 8 bits
                                            now.
32B1    RS-NRMLSE   EX      DE,HL           Pointer to DE, number to HL.
32B2    RSTK-LOOP   DEC     B               Decrement the exponent on
                                            each shift.
                    ADD     HL,HL           Shift the number right one
                                            position.
                    JR      NC,32B2,RSTK-LOOP Until the carry is set.
                    RRC     C               Sign bit to carry flag now.
                    RR      H               Insert it in place as the number
                    RR      L               is shifted back one place -
                                            normal now.
                    EX      DE,HL           Pointer to byte 4 back to HL.
32BD    RS-STORE    DEC     HL              Point to the third location.
                    LD      (HL),E          Store the third byte.
                    DEC     HL              Point to the second location.
                    LD      (HL),D          Store the second byte.
                    DEC     HL              Point to the first location.
                    LD      (HL),B          Store the exponent byte.
                    POP     DE              Restore the 'other' pointer to
                                            DE.
                    RET                     Finished.
```

THE FLOATING-POINT CALCULATOR

THE TABLE OF CONSTANTS

This first table holds the five useful and frequently needed numbers zero, one, a half, a half of pi and ten. The numbers are held in a condensed form which is expanded by the STACK LITERALS subroutine, see below, to give the required floating-point form.

		data:	**constant**	**when expanded gives: exp. mantissa: (Hex.)**
32C5	stk-zero	DEFB +00 DEFB +B0 DEFB +00	zero	00 00 00 00 00
32C8	stk-one	DEFB +40 DEFB +B0 DEFB +00 DEFB +01	one	00 00 01 00 00
32CC	stk-half	DEFB +30 DEFB +00	a half	80 00 00 00 00
32CE	stk-pi/2	DEFB +F1 DEFB +49 DEFB +0F DEFB +DA DEFB +A2	a half of pi	81 49 0F DA A2
32D3	stk-ten	DEFB +40 DEFB +B0 DEFB +00 DEFB +0A	ten	00 00 0A 00 00

THE TABLE OF ADDRESSES:

This second table is a look-up table of the addresses of the sixty-six operational subroutines of the calculator. The offsets used to index into the table are derived either from the operation codes used in SCANNING, see 2734, etc., or from the literals that follow a RST 0028 instruction.

	offset	**label**	**address**		**offset**	**label**	**address**
32D7	00	jump-true	8F 36	3319	21	tan	DA 37
32D9	01	exchange	3C 34	331B	22	asn	33 38
32DB	02	delete	A1 33	331D	23	acs	43 38
32DD	03	subtract	0F 30	331F	24	atn	E2 37
32DF	04	multiply	CA 30	3321	25	ln	13 37
32E1	05	division	AF 31	3323	26	exp	C4 36
32E3	06	to-power	51 38	3325	27	int	AF 36
32E5	07	or	1B 35	3327	28	sqr	4A 38
32E7	08	no-&-no	24 35	3329	29	sgn	92 34
32E9	09	no-l-eql	3B 35	332B	2A	abs	6A 34

32EB	0A	no-gr-eq	3B 35	332D	2B	peek	AC 34
32ED	0B	nos-neql	3B 35	332F	2C	in	A5 34
32EF	0C	no-grtr	3B 35	3331	2D	usr-no	B3 34
32F1	0D	no-less	3B 35	3333	2E	str$	1F 36
32F3	0E	nos-eql	3B 35	3335	2F	chr$	C9 35
32F5	0F	addition	14 30	3337	30	not	01 35
32F7	10	str-&-no	2D 35	3339	31	duplicate	C0 33
32F9	11	str-l-eql	3B 35	333B	32	n-mod-m	A0 36
32FB	12	str-gr-eq	3B 35	333D	33	jump	86 36
32FD	13	strs-neql	3B 35	333F	34	stk-data	C6 33
32FF	14	str-grtr	3B 35	3341	35	dec-jr-nz	7A 36
3301	15	str-less	3B 35	3343	36	less-0	06 35
3303	16	strs-eql	3B 35	3345	37	greater-0	F9 34
3305	17	strs-add	9C 35	3347	38	end-calc	9B 36
3307	18	val$	DE 35	3349	39	get-argt	83 37
3309	19	usr-$	BC 34	334B	3A	truncate	14 32
330B	1A	read-in	45 36	334D	3B	fp-calc-2	A2 33
330D	1B	negate	6E 34	334F	3C	e-to-fp	4F 2D
330F	1C	code	69 36	3351	3D	re-stack	97 32
3311	1D	val	DE 45	3353	3E	series-06 etc.	49 34
3313	1E	len	74 36	3355	3F	stk-zero etc.	1B 34
3315	1F	sin	B5 37	3357	40	st-mem-0 etc.	2D 34
3317	20	cos	AA 37	3359	41	get-mem-0 etc.	0F 34

Note: The last four subroutines are multi-purpose subroutines and are entered with a parameter that is a copy of the right hand five bits of the original literal. The full set follows:

Offset 3E: series-06, series-08, & series-0C; literals 86,88 & 8C.
Offset 3F: stk-zero, stk-one, stk-half, stk-pi/2 & stk-ten; literals A0 to A4.
Offset 40: st-mem-0, st-mem-1, st-mem-2, st-mem-3, st-mem-4 & st-mem-5; literals C0 to C5.
Offset 41: get-mem-0, get-mem-1, get-mem-2, get-mem-3, get-mem-4 & get-mem-5; literals E0 to E5.

THE 'CALCULATE' SUBROUTINE

This subroutine is used to perform floating-point calculations. These can be considered to be of three types:

I. Binary operations, e.g. addition, where two numbers in floating-point form are added together to give one 'last value'.

II. Unary operations, e.g. sin, where the 'last value' is changed to give the appropriate function result as a new 'last value'.

III. Manipulatory operations, e.g. st-mem-0, where the 'last value' is copied to the first five bytes of the calculator's memory area.

The operations to be performed are specified as a series of data-bytes, the literals, that follow an RST 0028 instruction that calls this subroutine. The last literal in the list is always '38' which leads to an end to the whole operation.

In the case of a single operation needing to be performed, the operation offset can be passed to the CALCULATOR in the B register, and operation '3B', the SINGLE CALCULATION operation, performed.

It is also possible to call this subroutine recursively, i.e. from within itself, and in such a case it is possible to use the system variable BREG as a counter that controls how many operations are performed before returning.

The first part of this subroutine is complicated but essentially it performs the two tasks of setting the registers to hold their required values, and to produce an offset, and possibly a parameter, from the literal that is currently being considered.

The offset is used to index into the calculator's table of addresses, see above, to find the required subroutine address.

The parameter is used when the multi-purpose subroutines are called.

Note: A floating-point number may in reality be a set of string parameters.

335B	CALCULATE	CALL	35BF,STK-PNTRS	Presume a unary operation and therefore set HL to point to the start of the 'last value' on the calculator stack and DE one-past this floating-point number (STKEND).
335E	GEN-ENT-1	LD LD	A,B (BREG),A	Either, transfer a single operation offset to BREG temporarily, or, when using the subroutine recursively pass the parameter to BREG to be used as a counter.
3362	GEN-ENT-2	EXX EX EXX	 (SP),HL	The return address of the sub-routine is store in H'L'. This saves the pointer to the first literal. Entering the CALCUL-ATOR at GEN-ENT-2 is used whenever BREG is in use as a counter and is not to be disturbed.
3365	RE-ENTRY	LD	(STKEND),DE	A loop is now entered to handle each literal in the list that follows the calling instruction; so first, always set to STKEND.
		EXX LD	 A,(HL)	Go to the alternate register set, and fetch the literal for this loop.

		INC	HL	Make H'L' point to the next literal.
336C	SCAN-ENT	PUSH	HL	This pointer is saved briefly on the machine stack. SCAN-ENT is used by the SINGLE CALCULATION subroutine to find the subroutine that is required.
		AND	A	Test the A register.
		JP	P,3380,FIRST-3D	Separate the simple literals from the multi-purpose literals. Jump with literals 00 - 3D.
		LD	D,A	Save the literal in D.
		AND	+60	Continue only with bits 5 & 6.
		RRCA		Four right shifts make them
		RRCA		now bits 1 & 2.
		RRCA		
		RRCA		
		ADD	A,+7C	The offsets required are 3E-41.
		LD	L,A	and L will now hold double the required offset.
		LD	A,D	Now produce the parameter by
		AND	+1F	taking bits 0,1,2,3 & 4 of the literal; keep the parameter in A.
		JR	338E,ENT-TABLE	Jump forward to find the address of the required subroutine.
3380	FIRST-3D	CP	+18	Jump forward if performing a
		JR	NC,338C,DOUBLE-A	unary operation.
		EXX		All of the subroutines that perform binary operations require
		LD	BC,+FFFB	
		LD	D,H	that HL points to the first operand
		LD	E,L	and DE points to the second
		ADD	HL,BC	operand (the 'last value') as they
		EXX		appear on the calculator stack.
338C	DOUBLE-A	RLCA		As each entry in the table of
		LD	L,A	addresses takes up two bytes the offset produced is doubled.
338E	ENT-TABLE	LD	DE,+32D7	The base address of the table.
		LD	H,+00	The address of the required
		ADD	HL,DE	table entry is formed in HL; and
		LD	E,(HL)	the required subroutine address
		INC	HL	is loaded into the DE register
		LD	D,(HL)	pair.
		LD	HL,+3365	The RE-ENTRY address of 3365
		EX	(SP),HL	is put on the machine stack
		PUSH	DE	underneath the subroutine address.
		EXX		Return to the main set of registers.
		LD	BC,(STKEND-hi)	The current value of BREG is transferred to the B register thereby returning the single operation offset. (See COMPARISON at 353B)
33A1	delete	RET		An indirect jump to the required subroutine.

THE 'DELETE' SUBROUTINE

(Offset 02: 'delete)

This subroutine contains only the single RET instruction at 33A1, above. The literal '02' results in this subroutine being considered as a binary operation that is to be entered with a first number addressed by the HL register pair and a second number addressed by the DE register pair, and the result produced again addressed by the HL register pair.
The single RET instruction thereby leads to the first number being considered as the resulting 'last value' and the second number considered as being deleted. Of course the number has not been deleted from the memory but remains inactive and will probably soon be overwritten.

THE 'SINGLE OPERATION' SUBROUTINE

(Offset 3B: 'fp-calc-2')

This subroutine is only called from SCANNING at 2757 hex and is used to perform a single arithmetic operation. The offset that specifies which operation is to be performed is supplied to the calculator in the B register and subsequently transferred to the system variable BREG.

The effect of calling this subroutine is essentially to make a jump to the appropriate subroutine for the single operation.

33A2	fp-calc-2	POP	AF	Discard the RE-ENTRY address.
		LD	A,(BREG)	Transfer the offset to A.
		EXX		Enter the alternate register set.
		JR	336C,SCAN-ENT	Jump back to find the required address; stack the RE-ENTRY address and jump to the subroutine for the operation.

THE 'TEST 5-SPACES' SUBROUTINE

This subroutine tests whether there is sufficient room in memory for another 5-byte floating-point number to be added to the calculator stack.

33A9	TEST-5-SP	PUSH	DE	Save DE briefly.
		PUSH	HL	Save HL briefly.
		LD	BC,+0005	Specify the test is for 5 bytes.
		CALL	1F05,TEST-ROOM	Make the test.
		POP	HL	Restore HL.
		POP	DE	Restore DE.
		RET		Finished.

THE 'STACK NUMBER' SUBROUTINE

This subroutine is called by BEEP and SCANNING twice to copy STKEND to DE, move a floating-point number to the calculator stack, and reset STKEND from DE. It calls 'MOVE-FP' to do the actual move.

33B4	STACK-NUM	LD	DE,(STKEND)	Copy STKEND to DE as destination address.
		CALL	33C0,MOVE-FP	Move the number.
		LD	(STKEND),DE	Reset STKEND from DE.
		RET		Finished.

THE 'MOVE A FLOATING-POINT NUMBER' SUBROUTINE

(Offset 31: 'duplicate')

This subroutine moves a floating-point number to the top of the calculator stack (3 cases) or from the top of the stack to the calculator's memory area (1 case). It is also called through the calculator when it simply duplicates the number at the top of the calculator stack, the 'last value', thereby extending the stack by five bytes.

33C0	MOVE-FP	CALL	33A9,TEST-5-SP	A test is made for room.
		LDIR		Move the five bytes involved.
		RET		Finished.

THE 'STACK LITERALS' SUBROUTINE

(Offset 34: 'stk-data')

This subroutine places on the calculator stack, as a 'last value', the floating-point number supplied to it as 2, 3, 4 or 5 literals.
When called by using offset '34' the literals follow the '34' in the list of literals; when called by the SERIES GENERATOR, see below, the literals are supplied by the sub-routine that called for a series to be generated; and when called by SKIP CONSTANTS & STACK A CONSTANT the literals are obtained from the calculator's table of constants (32C5-32D6).
In each case, the first literal supplied is divided by Hex.40, and the integer quotient plus 1 determines whether 1, 2, 3 or 4 further literals will be taken from the source to form the mantissa of the number. Any unfilled bytes of the five bytes that go to form a 5-byte floating-point number are set to zero. The first literal is also used to determine the exponent, after reducing mod Hex.40, unless the remainder is zero, in which case the second literal is used, as it stands, without reducing mod Hex.40. In either case, Hex.50 is added to the literal, giving the augmented exponent byte, e (the true exponent e' plus Hex.80). The rest of the 5 bytes are stacked, including any zeros needed, and the subroutine returns.

33C6	STK-DATA	LD	H,D	This subroutine performs the
		LD	L,E	manipulatory operation of adding a 'last value' to the calculator stack; hence HL is set to point one-past the present 'last value' and hence point to the result.
33C8	STK-CONST	CALL	33A9,TEST-5-SP	Now test that there is indeed room.
		EXX		Go to the alternate register set
		PUSH	HL	and stack the pointer to the
		EXX		next literal.
		EX	(SP),HL	Switch over the result pointer and the next literal pointer.
		PUSH	BC	Save BC briefly.
		LD	A,(HL)	The first literal is put into A
		AND	+C0	and divided by Hex.40 to give
		RLCA		the integer values 0, 1, 2 or 3.
		RLCA		
		LD	C,A	The integer value is transferred
		INC	C	to C and incremented, thereby giving the range 1, 2, 3 or 4 for the number of literals that will be needed.
		LD	A,(HL)	The literal is fetch anew,
		AND	+3F	reduced mod Hex.40 and dis-
		JR	NZ,33DE,FORM-EXP	carded as inappropriate if the
		INC	HL	remainder if zero; in which case

		LD	A,(HL)	the next literal is fetched and used unreduced.
33DE	FORM-EXP	ADD	A,+50	The exponent, e, is formed by
		LD	(DE),A	the addition of Hex.50 and passed to the calculator stack as the first of the five bytes of the result.
		LD	A,+05	The number of literals specified
		SUB	C	in C are taken from the source
		INC	HL	and entered into the bytes of
		INC	DE	the result.
		LD	B,+00	
		LDIR		
		POP	BC	Restore BC.
		EX	(SP),HL	Return the result pointer to HL
		EXX		and the next literal pointer to
		POP	HL	its usual position in H' & L'.
		EXX		
		LD	B,A	The number of zero bytes
		XOR	A	required at this stage is given by
33F1	STK-ZEROS	DEC	B	5-C-1; and this number of zeros
		RET	Z	is added to the result to make
		LD	(DE),A	up the required five bytes.
		INC	DE	
		JR	33F1, STK-ZEROS	

THE 'SKIP CONSTANTS' SUBROUTINE

This subroutine is entered with the HL register pair holding the base address of the calculator's table of constants and the A register holding a parameter that shows which of the five constants is being requested.
The subroutine performs the null operations of loading the five bytes of each unwanted constant into the locations 0000, 0001, 0002, 0003 and 0004 at the beginning of the ROM until the requested constant is reached.
The subroutine returns with the HL register pair holding the base address of the requested constant within the table of constants.

33F7	SKIP-CONS	AND	A	The subroutine returns if the
33F8	SKIP-NEXT	RET	Z	parameter is zero, or when the requested constant has been reached.
		PUSH	AF	Save the parameter.
		PUSH	DE	Save the result pointer.
		LD	DE,+0000	The dummy address.
		CALL	33C8,STK-CONST	Perform imaginary stacking of an expanded constant.
		POP	DE	Restore the result pointer.
		POP	AF	Restore the parameter.
		DEC	A	Count the loops.
		JR	33F8,SKIP-NEXT	Jump back to consider the value of the counter.

THE 'MEMORY LOCATION' SUBROUTINE

This subroutine finds the base address for each five byte portion of the calculator's memory area to or from which a floating-point number is to be moved from or to the calculator stack. It does this operation by adding five times the parameter supplied to the base address for the area which is held in the HL register pair.
Note that when a FOR-NEXT variable is being handled then the pointers are changed so that the variable is treated as if it were the calculator's memory area (see address 1D20).

3406	LOC-MEM	LD	C,A	Copy the parameter to C.
		RLCA		Double the parameter.
		RLCA		Double the result.
		ADD	A,C	Add the value of the parameter to give five times the original

```
                                        value.
              LD        C,A             This result is wanted in the
              LD        B,+00           BC register pair.
              ADD       HL,BC           Produce the new base address.
              RET                       Finished.
```

THE 'GET FROM MEMORY AREA' SUBROUTINE

(Offsets E0 to E5: 'get-mem-0' to 'get-mem-5')

This subroutine is called using the literals E0 to E5 and the parameter derived from these literals is held in the A register. The subroutine calls MEMORY LOCATION to put the required source address into the HL register pair and MOVE A FLOATING-POINT NUMBER to copy the five bytes involved from the calculator's memory area to the top of the calculator stack to form a new 'last value'.

```
340F  get-mem-0   PUSH      DE              Save the result pointer.
      etc.        LD        HL,(MEM)        Fetch the pointer to the current
                                            memory area (see above).
                  CALL      3406,LOC-MEM    The base address is found.
                  CALL      33C0,MOVE-FP    The five bytes are moved.
                  POP       HL              Set the result pointer.
                  RET                       Finished.
```

THE 'STACK A CONSTANT' SUBROUTINE

(offsets A0 to A4: 'stk-zero','stk-one','stk-half','stk-pi/2' & 'stk-ten')

This subroutine uses SKIP CONSTANTS to find the base address of the requested constants from the calculator's table of constants and then calls STACK LITERALS, entering at STK-CONST, to make the expanded form of the constant the 'last value' on the calculator stack.

```
341B  stk-zero    LD        H,D             Set HL to hold the result
      etc.                                  pointer.
                  LD        L,E
                  EXX                       Go to the alternate register set
                  PUSH      HL              and save the next literal pointer.
                  LD        HL,+32C5        The base address of the calcul-
                                            ator's table of constants.
                  EXX                       Back to the main set of registers.
                  CALL      33F7,SKIP-CONS  Find the requested base address.
                  CALL      33C8,STK-CONST  Expand the constant.
                  EXX
                  POP       HL              Restore the next literal pointer.
                  EXX
                  RET                       Finished.
```

THE 'STORE IN MEMORY AREA' SUBROUTINE

(Offsets C0 to C5: 'st-mem-0' to 'st-mem-5')

This subroutine is called using the literals C0 to C5 and the parameter derived from these literals is held in the A register. This subroutine is very similar to the GET FROM MEMORY subroutine but the source and destination pointers are exchanged.

```
342D  st-mem-0    PUSH      HL              Save the result pointer.
      etc.        EX        DE,HL           Source to DE briefly.
                  LD        HL,(MEM)        Fetch the pointer to the current
                                            memory area.
                  CALL      3406,LOC-MEM    The base address is found.
                  EX        DE,HL           Exchange source and
                                            destination pointers.
                  CALL      33C0,MOVE-FP    The five bytes are moved.
                  EX        DE,HL           'Last value' +5, i.e. STKEND, to
                                            DE.
                  POP       HL              Result pointer to HL.
                  RET                       Finished.
```

Note that the pointers HL and DE remain as they were, pointing to STKEND-5 and STKEND respectively, so that the 'last value' remains on the calculator stack. If required it can be removed by using 'delete'.

THE 'EXCHANGE' SUBROUTINE

(Offset 01: 'exchange')

This binary operation 'exchanges' the first number with the second number, i.e. the topmost two numbers on the calculator stack are exchanged.

```
343C    EXCHANGE    LD      B,+05           There are five bytes involved.
343E    SWAP-BYTE   LD      A,(DE)          Each byte of the second number.
                    LD      C,(HL)          Each byte of the first number.
                    EX      DE,HL           Switch source and destination.
                    LD      (DE),A          Now to the first number.
                    LD      (HL),C          Now to the second number
                    INC     HL              Move to consider the next pair
                    INC     DE              of bytes.
                    DJNZ    343E,SWAP-BYTE  Exchange the five bytes.
                    EX      DE,HL           Get the pointers correct as the
                                            number 5 is an odd number.
                    RET                     Finished.
```

THE 'SERIES GENERATOR' SUBROUTINE

(Offsets 86,88 & 8C: 'series-06','series-08' & 'series-0C')

This important subroutine generates the series of Chebyshev polynomials which are used to approximate to SIN, ATN, LN and EXP and hence to derive the other arithmetic functions which depend on these (COS, TAN, ASN, ACS, ** and SQR).
The polynomials are generated, for n=1,2,..., by the recurrence relation:

$T_{n+1}(z) = 2zT_n(z) - T_{n-1}(z)$, where $T_n(z)$ is the nth Chebyshev polynomial in z.
The series in fact generates:
T_0, $2T_1$, 2T2,.... , $2T_{n-1}$, where n is 6 for SIN, 8 for EXP and 12 decimal, for LN and ATN.
The coefficients of the powers of z in these polynomials may be found in the Handbook of Mathematical Functions by M. Abramowitz and I.A. Stegun (Dover 1965), page 795.
BASIC programs showing the generation of each of the four functions are given here in the Appendix.
In simple terms this subroutine is called with the 'last value' on the calculator stack, say Z, being a number that bears a simple relationship to the argument, say X, when the task is to evaluate, for instance, SIN X. The calling subroutine also supplies the list of constants that are to be required (six constants for SIN). The SERIES GENERATOR then manipulates its data and returns to the calling routine a 'last value' that bears a simple relationship to the requested function, for instance, SIN X.
This subroutine can be considered to have four major parts:

i. The setting of the loop counter:
The calling subroutine passes its parameters in the A register for use as a counter. The calculator is entered at GEN-ENT-1 so that the counter can be set.

```
3449    series-06   LD      B,A             Move the parameter to B.
        etc.        CALL    335E,GEN-ENT-1  In effect a RST 0028
                                            instruction but sets the counter.
```

ii. The handling of the 'last value', Z:
The loop of the generator requires 2*Z to be placed in mem-0, zero to be placed in mem-2 and the 'last value' to be zero.

```
                                            calculator stack
                    DEFB    +31,duplicate   Z,Z
                    DEFB    +0F,addition    2*Z
                    DEFB    +C0,st-mem-0    2*Z         mem-0 holds 2*Z
                    DEFB    +02,delete      -
```

```
                DEFB    +A0,stk-zero        0
                DEFB    +C2,st-mem-2        0       mem-2 holds 0
```

iii. The main loop:

The series is generated by looping, using BREG as a counter; the constants in the calling subroutine are stacked in turn by calling STK-DATA; the calculator is re-entered at GEN-ENT-2 so as not to disturb the value of BREG; and the series is built up in the form: B(R) = 2*Z*B(R-1) - B(R-2) + A(R), for R = 1,2,...,N, where A(1), A(2),..., A(N) are the constants supplied by the calling subroutine (SIN, ATN, LN and EXP) and B(0) = 0 = B(-1).

The (R+1)th loop starts with B(R) on the stack and with 2*Z, B(R-2) and B(R-1) in mem-0, mem-1 and mem-2 respectively.

```
3453    G-LOOP      DEFB    +31,duplicate       B(R),B(R)
                    DEFB    +E0,get-mem-0       B(R),B(R),2*Z
                    DEFB    +04,multiply        B(R),2*B(R)*Z
                    DEFB    +E2,get-mem-2       B(R),2*B(R)*Z,B(R-1)
                    DEFB    +C1,st-mem-1        mem-1 holds B(R-1)
DEFB    +38,end-calc DEFB   +03,subtract        B(R),2*B(R)*Z-B(R-1)
```

The next constant is placed on the calculator stack.

```
                CALL    33C6,STK-DATA       B(R),2*B(R)*Z-B(R-1),A(R+1)
```

The Calculator is re-entered without disturbing BREG.

```
                CALL    3362,GEN-ENT-2
                DEFB    +0F,addition        B(R),2*B(R)*Z-B(R-1)+A(R+1)
                DEFB    +01,exchange        2*B(R)*Z-B(R-1)+A(R+1),B(R)
                DEFB    +C2,st-mem-2        mem-2 holds B(R)
                DEFB    +02,delete          2*B(R)*Z-B(R-1)+A(R!1) =
                                            B(R!1)
                DEFB    +35,dec-jr-nz       B(R+1)
                DEFB    +EE,to 3453,G-LOOP
```

iv. The subtraction of B(N-2):

The loop above leaves B(N) on the stack and the required result is given by B(N) - B(N-2).

```
                DEFB    +E1,get-mem-1       B(N),B(N-2)
                DEFB    +03,subtract        B(N)-B(N-2)
                DEFB    +38,end-calc
                RET                         Finished
```

THE 'ABSOLUTE MAGNITUDE' FUNCTION

(Offset 2A: 'abs')

This subroutine performs its unary operation by ensuring that the sign bit of a floating-point number is reset. 'Small integers' have to be treated separately. Most of the work is shared with the 'unary minus' operation.

```
346A    abs         LD      B,+FF           B is set to FF hex.
                    JR      3474,NEG-TEST   The jump is made into 'unary
                                            minus'.
```

THE 'UNARY MINUS' OPERATION

(Offset 1B: 'negate')

This subroutine performs its unary operation by changing the sign of the 'last value' on the calculator stack. Zero is simply returned unchanged. Full five byte floating-point numbers have their sign bit manipulated so that it ends up reset (for 'abs') or changed (for 'negate'). 'Small integers' have their sign byte set to zero (for 'abs') or changed (for 'negate').

```
346E    NEGATE      CALL    34E9,TEST-ZERO  If the number is zero, the
                    RET     C               subroutine returns leaving
                                            00 00 00 00 00 unchanged.
```

```
                LD      B,+00           B is set to +00 hex for 'negate'.
```

'ABS' enters here.

```
3474  NEG-TEST  LD      A,(HL)          If the first byte is zero, the
                AND     A               jump is made to deal with a
                JR      Z,3483,INT-CASE 'small integer'.
                INC     HL              Point to the second byte.
                LD      A,B             Get +FF for 'abs', +00 for
                                        'negate'.
                AND     +80             Now +80 for 'abs', +00 for
                                        'negate'.
                OR      (HL)            This sets bit 7 for 'abs', but
                                        changes nothing for 'negate'.
                RLA                     Now bit 7 is changed, leading to
                CCF                     bit 7 of byte 2 reset for 'abs',
                RRA                     and simply changed for 'negate'.
                LD      (HL),A          The new second byte is stored.
                DEC     HL              HL points to the first byte
                                        again.
                RET                     Finished.
```

The 'integer case' does a similar operation with the sign byte.

```
3483  INT-CASE  PUSH    DE              Save STKEND in DE.
                PUSH    HL              Save pointer to the number in
                                        HL.
                CALL    2D7F,INT-FETCH  Fetch the sign in C, the number
                                        in DE.
                POP     HL              Restore the pointer to the
                                        number in HL.
                LD      A,B             Get +FF for 'abs', +00 for
                                        'negate'.
                OR      C               Now +FF for 'abs', no change for
                                        'negate'
                CPL                     Now +00 for 'abs', and a changed byte
                LD      C,A             for 'negate': store it in C.
                CALL    2D8E,INT-STORE  Store result on the stack.
                POP     DE              Return STKEND to DE.
                RET
```

THE 'SIGNUM' FUNCTION

(Offset 29: 'sgn')

This subroutine handles the function SGN X and therefore returns a 'last value' of 1 if X is positive, zero if X is zero and -1 if X is negative.

```
3492  sgn       CALL 34E9,TEST-ZERO     If X is zero, just return with
                RET     C               zero as the 'last value'.
                PUSH    DE              Save the pointer to STKEND.
                LD      DE,+0001        Store 1 in DE.
                INC     HL              Point to the second byte of X.
                RL      (HL)            Rotate bit 7 into the carry flag.
                DEC     HL              Point to the destination again.
                SBC     A,A             Set C to zero for positive X and
                LD      C,A             to FF hex for negative X.
                CALL    2D8E,INT-STORE  Stack 1 or -1 as required.
                POP     DE              Restore the pointer to
                                        STKEND'
                RET                     Finished.
```

THE 'IN' FUNCTION

(Offset 2C: 'in')

This subroutine handles the function IN X. It inputs at processor level from port X, loading BC with X and performing the instruction IN A,(C).

```
34A5  in      CALL  1E99,FIND-INT2  The 'last value', X, is
                                    compressed into BC.
              IN    A,(C)           The signal is received.
              JR    34B0,IN-PK-STK  Jump to stack the result.
```

THE 'PEEK' FUNCTION

(Offset 2B: 'peek')

This subroutine handles the function PEEK X. The 'last value' is unstacked by calling FIND-INT2 and replaced by the value of the contents of the required location.

```
34AC  peek    CALL  1E99,FIND-INT2  Evaluate the 'last value',
                                    rounded to the nearest integer;
                                    test that it is in range and return
                                    it in BC.
              LD    A,(BC)          Fetch the required byte.
34B0  IN-PK-STK JP  2D28,STACK-A    Exit by jumping to STACK-A.
```

THE 'USR' FUNCTION

(Offset 2D: 'usr-no')

This subroutine ('USR number' as distinct from 'USR string') handles the function USR X, where X is a number. The value of X is obtained in BC, a return address is stacked and the machine code is executed from location X.

```
34B3  usr-no  CALL  1E99,FIND-INT2  Evaluate the 'last value',
                                    rounded to the nearest integer;
                                    test that it is in range and return
                                    it in BC.
              LD    HL,+2D2B        Make the return address be that
              PUSH  HL              of the subroutine STACK-BC.
              PUSH  BC              Make an indirect jump to the
              RET                   required location.
```

Note: It is interesting that the IY register pair is re-initialised when the return to STACK-BC has been made, but the important H'L' that holds the next literal pointer is not restored should it have been disturbed. For a successful return to BASIC, H'L' must on exit from the machine code contain the address in SCANNING of the 'end-calc' instruction, 2758 hex (10072 decimal).

THE 'USR-STRING' FUNCTION

(Offset 19: 'usr-$')

This subroutine handles the function USR X$, where X$ is a string. The subroutine returns in BC the address of the bit pattern for the user-defined graphic corresponding to X$. It reports error A if X$ is not a single letter between a and u or a user-defined graphic.

```
34BC  usr-$   CALL  2BF1,STK-FETCH  Fetch the parameters of the
                                    string X$.
              DEC   BC              Decrease the length by 1 to test
                                    it.
              LD    A,B             If the length was not 1, then
              OR    C               jump to give error report A.
              JR    NZ,34E7,REPORT-A
              LD    A,(DE)          Fetch the single code of the
                                    string.
              CALL  2C8D,ALPHA      Does it denote a letter?
              JR    C,34D3,USR-RANGE If so, jump to gets its address.
              SUB   +90             Reduce range for actual user-
                                    defined graphics to 0 - 20
                                    decimal.
              JR    C,34E7,REPORT-A Give report A if out of range.
              CP    +15             Test the range again.
              JR    NC,34E7,REPORT-A Give report A if out of range.
              INC   A               Make range of user-defined
                                    graphics 1 to 21 decimal, as for
                                    a to u.
```

```
34D3  USR-RANGE  DEC   A              Now make the range 0 to 20
                                      decimal in each case.
                 ADD   A,A            Multiply by 8 to get an offset
                 ADD   A,A            for the address.
                 ADD   A,A
                 CP    +A8            Test the range of the offset.
                 JR    NC,34E7,REPORT-A  Give report A if out of range.
                 LD    BC,(UDG)       Fetch the address of the first
                                      user-defined graphic in BC.
                 ADD   A,C            Add C to the offset.
                 LD    C,A            Store the result back in C.
                 JR    NC,34E4,USR-STACK  Jump if there is no carry.
                 INC   B              Increment B to complete the
                                      address.
34E4  USR-STACK  JP    2D2B,STACK-BC  Jump to stack the address.
```

REPORT A - Invalid argument.

```
34E7  REPORT-A   RST   0008,ERROR-1  Call the error handling
                 DEFB  +09            routine.
```

THE 'TEST-ZERO' SUBROUTINE

This subroutine is called at least nine times to test whether a floating-point number is zero. This test requires that the first four bytes of the number should each be zero. The subroutine returns with the carry flag set if the number was in fact zero.

```
34E9  TEST-ZERO  PUSH  HL             Save HL on the stack.
                 PUSH  BC             Save BC on the stack.
                 LD    B,A            Save the value of A in B.
                 LD    A,(HL)         Get the first byte.
                 INC   HL             Point to the second byte.
                 OR    (HL)           OR first byte with second.
                 INC   HL             Point to the third byte.
                 OR    (HL)           OR the result with the third
                                      byte.
                 INC   HL             Point to the fourth byte.
                 OR    (HL)           OR the result with the fourth
                                      byte.
                 LD    A,B            Restore the original value of A.
                 POP   BC             And of BC.
                 POP   HL             Restore the pointer to the
                                      number to HL.
                 RET   NZ             Return with carry reset if any of
                                      the four bytes was non-zero.
                 SCF                  Set the carry flag to indicate
                 RET                  that the number was zero, and
                                      return.
```

THE 'GREATER THAN ZERO' OPERATION

(Offset 37: 'greater-0')

This subroutine returns a 'last value' of one if the present 'last value' is greater than zero and zero otherwise. It is also used by other subroutines to 'jump on plus'.

```
34F9  GREATER-0  CALL  34E9,TEST-ZERO  Is the 'last-value' zero?
                 RET   C               If so, return.
                 LD    A,+FF           Jump forward to LESS THAN
                 JR    3507,SIGN-TO-C  ZERO but signal the opposite
                                       action is needed.
```

THE 'NOT' FUNCTION

(Offset 30: 'not')

This subroutine returns a 'last value' of one if the present 'last value' is zero and zero otherwise. It is also used by other subroutines to 'jump on zero'.

```
3501    NOT         CALL    34E9,TEST-ZERO  The carry flag will be set only if
                                            the 'last value' is zero; this gives
                                            the correct result.
                    JR      350B,FP-0/1     Jump forward.
```

THE 'LESS THAN ZERO' OPERATION

(Offset 36: 'less-0')

This subroutine returns a 'last value' of one if the present 'last value' is less than zero and zero otherwise. It is also used by other subroutines to 'jump on minus'.

```
3506    less-0      XOR     A               Clear the A register.
3507    SIGN-TO-C   INC     HL              Point to the sign byte.
                    XOR     (HL)            The carry is reset for a positive
                    DEC     HL              number and set for a negative
                    RLCA                    number; when entered from
                                            GREATER-0 the opposite sign
                                            goes to the carry.
```

THE 'ZERO OR ONE' SUBROUTINE

This subroutine sets the 'last value' to zero if the carry flag is reset and to one if it is set. When called from 'E-TO-FP' however it creates the zero or one not on the stack but in mem-0.

```
350B    FP-0/1      PUSH    HL              Save the result pointer.
                    LD      A,+00           Clear A without disturbing the
                                            carry.
                    LD      (HL),A          Set the first byte to zero.
                    INC     HL              Point to the second byte.
                    LD      (HL),A          Set the second byte to zero.
                    INC     HL              Point to the third byte.
                    RLA                     Rotate the carry into A, making
                                            A one if the carry was set, but
                                            zero if the carry was reset.
                    LD      (HL),A          Set the third byte to one or
                                            zero.
                    RRA                     Ensure that A is zero again.
                    INC     HL              Point to the fourth byte.
                    LD      (HL),A          Set the fourth byte to zero.
                    INC     HL              Point to the fifth byte.
                    LD      (HL),A          Set the fifth byte to zero.
                    POP     HL              Restore the result pointer.
                    RET
```

THE 'OR' OPERATION

(Offset 07: 'or')

This subroutine performs the binary operation 'X OR Y' and returns X if Y is zero and the value 1 otherwise.

```
351B    or          EX      DE,HL           Point HL at Y, the second
                                            number.
                    CALL    34E9,TEST-ZERO  Test whether Y is zero.
                    EX      DE,HL           Restore the pointers.
                    RET     C               Return if Y was zero; X is now
                                            the 'last value'.
                    SCF                     Set the carry flag and jump back
                    JR      350B,FP-0/1     to set the 'last value' to 1.
```

THE 'NUMBER AND NUMBER' OPERATION

(Offset 08: 'no-&-no')

This subroutine performs the binary operation 'X AND Y' and returns X if Y is non-zero and the value zero otherwise.

```
3524    no-&-no     EX      DE,HL           Point HL at Y, DE at X.
                    CALL    34E9,TEST-ZERO  Test whether Y is zero.
                    EX      DE,HL           Swap the pointers back.
                    RET     NC              Return with X as the 'last value'
                                            if Y was non-zero.
                    AND     A               Reset the carry flag and jump
                    JR      350B,FP-0/1     back to set the 'last value' to
                                            zero.
```

THE 'STRING AND NUMBER' OPERATION

(Offset 10: 'str-&-no')

This subroutine performs the binary operation 'X$ AND Y' and returns X$ if Y is non-zero and a null string otherwise.

```
352D    str-&-no    EX      DE,HL           Point HL at Y, DE at X$
                    CALL    34E9,TEST-ZERO  Test whether Y is zero.
                    EX      DE,HL           Swap the pointers back.
                    RET     NC              Return with X$ as the 'last
                                            value' if Y was non-zero.
                    PUSH    DE              Save the pointer to the number.
                    DEC     DE              Point to the fifth byte of the
                                            string parameters i.e. length-
                                            high.
                    XOR     A               Clear the A register.
                    LD      (DE),A          Length-high is now set to zero.
                    DEC     DE              Point to length-low.
                    LD      (DE),A          Length-low is now set to zero.
                    POP     DE              Restore the pointer.
                    RET                     Return with the string
                                            parameters being the 'last value'.
```

THE 'COMPARISON' OPERATIONS

(Offsets 09 to 0E & 11 to 16: 'no-l-eql', 'no-gr-eq', 'nos-neql', 'no-grtr', 'no-less', 'nos-eql', 'str-l-eql', 'str-gr-eq', 'strs-neql', 'str-grtr', 'str-less' & 'strs-eql')

This subroutine is used to perform the twelve possible comparison operations. The single operation offset is present in the B register at the start of the subroutine.

```
353B    no-l-eql    LD      A,B             The single offset goes to the
        etc.                                A register.
                    SUB     +08             The range is now 01-06 &
                                            09-0E.
                    BIT     2,A             This range is changed to:
                    JR      NZ,3543,EX-OR-NOT 00-02, 04-06, 08-0A &
                    DEC     A               0C-0E.
3543    EX-OR-NOT   RRCA                    Then reduced to 00-07 with
                                            carry set for 'greater than or
                                            equal to' & 'less than'; the
                                            operations with carry set are
                    JR      NC,354E,NU-OR-STR then treated as their
                    PUSH    AF              complementary operation once
                    PUSH    HL              their values have been exchanged.
                    CALL    343C,EXCHANGE
                    POP     DE
                    EX      DE,HL
                    POP     AF
354E    NU-OR-STR   BIT     2,A             The numerical comparisons are
                    JR      NZ,3559,STRINGS now separated from the string
                                            comparisons by testing bit 2.
                    RRCA                    The numerical operations now
                                            have the range 00-01 with carry
                                            set for 'equal' and 'not equal'.
                    PUSH    AF              Save the offset.
                    CALL    300F,SUBTRACT   The numbers are subtracted for
```

```
                JR      358C,END-TESTS      the final tests.
3559  STRINGS   RRCA                        The string comparisons now
                                            have the range 02-03 with carry
                                            set for 'equal' and 'not equal'.
                PUSH    AF                  Save the offset.
                CALL    2BF1,STK-FETCH      The lengths and starting
                PUSH    DE                  addresses of the strings are
                PUSH    BC                  fetched from the calculator
                CALL    2BF1,STK-FETCH      stack.
                POP     HL                  The length of the second string.
3564  BYTE-COMP LD      A,H
                OR      L
                EX      (SP),HL
                LD      A,B
                JR      NZ,3575,SEC-PLUS    Jump unless the second string
                OR      C                   is null.
356B  SECND-LOW POP     BC                  Here the second string is either
                                            null or less than the first.
                JR      Z,3572,BOTH-NULL
                POP     AF
                CCF                         The carry is complemented to
                JR      3588,STR-TEST       give the correct test results.
3572  BOTH-NULL POP     AF                  Here the carry is used as it
                JR      3588,STR-TEST       stands.
3575  SEC-PLUS  OR      C
                JR      Z,3585,FRST-LESS    The first string is now null,
                                            the second not.
                LD      A,(DE)              Neither string is null, so their
                SUB     (HL)                next bytes are compared.
                JR      C,3585,FRST-LESS    The first byte is less.
                JR      NZ,356B,SECND-LOW   The second byte is less.
                DEC     BC                  The bytes are equal; so the
                INC     DE                  lengths are decremented and a
                INC     HL                  jump is made to BYTE-COMP
                EX      (SP),HL             to compare the next bytes of
                DEC     HL                  the reduced strings.
                JR      3564,BYTE-COMP
3585  FRST-LESS POP     BC
                POP     AF
                AND     A                   The carry is cleared here for the
                                            correct test results.
3588  STR-TEST  PUSH    AF                  For the string tests, a zero is
                RST     0028,FP-CALC        put on to the calculator stack.
                DEFB    +A0,stk-zero
                DEFB    +38,end-calc
358C  END-TESTS POP     AF                  These three tests, called as
                PUSH    AF                  needed, give the correct results
                CALL    C,3501,NOT          for all twelve comparisons. The
                POP     AF                  initial carry is set for 'not equal'
                PUSH    AF                  and 'equal', and the final carry
                CALL    NC,34F9,GREATER-0   is set for 'greater than', 'less
                POP     AF                  than' and 'equal'.
                RRCA
                CALL    NC,3501,NOT
                RET                         Finished.
```

THE 'STRING CONCATENATION' OPERATION

(Offset 17: 'strs-add')

This subroutine performs the binary operation 'A$+B$. The parameters for these strings are fetched and the total length found. Sufficient room to hold both the strings is made available in the work space and the strings are copied over. The result of this subroutine is therefore to produce a temporary variable A$+B$ that resides in the work space.

```
359C  strs-add   CALL  2BF1,STK-FETCH   The parameters of the second
                 PUSH  DE              string are fetched and saved.
                 PUSH  BC
                 CALL  2BF1,STK-FETCH  The parameters of the first
                                       string are fetched.
                 POP   HL
                 PUSH  HL              The lengths are now in HL and
                                       BC.
                 PUSH  DE              The parameters of the first
                 PUSH  BC              string are saved.
                 ADD   HL,BC           The total length of the two
                 LD    B,H             strings is calculated and passed
                 LD    C,L             to BC.
                 RST   0030,BC-SPACES  Sufficient room is made
                                       available.
                 CALL  2AB2,STK-STORE  The parameters of the new
                                       string are passed to the
                                       calculator stack.
                 POP   BC              The parameters of the first
                 POP   HL              string are retrieved and the
                 LD    A,B             string copied to the work space
                 OR    C               as long as it is not a null string.
                 JR    Z,35B7,OTHER-STR
                 LDIR
35B7  OTHER-STR  POP   BC              Exactly the same procedure is
                 POP   HL              followed for the second string
                 LD    A,B             thereby giving 'A$+B$'.
                 OR    C
                 JR    Z,35BF,STK-PNTRS
                 LDIR
```

THE 'STK-PNTRS' SUBROUTINE

This subroutine resets the HL register pair to point to the first byte of the 'last value', i.e. STKEND-5, and the DE register pair to point one-past the 'last value', i.e. STKEND.

```
35BF  STK-PNTRS  LD    HL,(STKEND)    Fetch the current value of
                                      STKEND.
                 LD    DE,+FFFB       Set DE to -5, twos complement.
                 PUSH  HL             Stack the value for STKEND.
                 ADD   HL,DE          Calculate STKEND-5.
                 POP   DE             DE now holds STKEND and HL
                 RET
```

THE 'CHR$' FUNCTION

(Offset 2F: 'chrs')

This subroutine handles the function CHR$ X and creates a single character string in the work space.

```
35C9  chrs       CALL 2DD5,FP-TO-A     The 'last value' is compressed
                                       into the A register.
                 JR    C,35DC,REPORT-B Give the error report if X was
                                       greater than 255 decimal, or
                 JR    NZ,35DC,REPORT-B X was a negative number.
                 PUSH  AF              Save the compressed value of X.
                 LD    BC,+0001        Make one space available in the
                 POP   AF              Fetch the value.
                 LD    (DE),A          Copy the value to the work
                                       space.
                 CALL  2AB2,STK-STORE  Pass the parameters of the new
                                       string to the calculator stack.
                 EX    DE,HL           Reset the pointers.
                 RET                   Finished.
```

REPORT-B - Integer out of range

35DC	REPORT-B	RST	0008,ERROR-1	Call the error handling
		DEFB	+0A	routine.

THE 'VAL' AND 'VAL$' FUNCTION

(Offsets 1D: 'val' and 18: 'val$')

This subroutine handles the functions VAL X$ and VAL$ X$. When handling VAL X$, it return a 'last value' that is the result of evaluating the string (without its bounding quotes) as a numerical expression. when handling VAL$ X$, it evaluates X$ (without its bounding quotes) as a string expression, and returns the parameters of that string expression as a 'last value' on the calculator stack.

35DE	val	LD	HL,(CH-ADD)	The current value of CH-ADD is
	(also val$)	PUSH	HL	preserved on the machine stack.
		LD	A,B	The 'offset' for 'val' or 'val$' must be in the B register; it is now copied to A.
		ADD	A,+E3	Produce +00 and carry set for 'val', +FB and carry reset for 'val$'.
		SBC	A,A	Produce +FF (bit 6 therefore set) for 'val', but +00 (bit 6 reset) for 'val$'.
		PUSH	AF	Save this 'flag' on the machine stack.
		CALL	2BF1,STK-FETCH	The parameters of the string are
		PUSH	DE	fetched; the starting address is
		INC	BC	saved; one byte is added to the
		RST	0030,BC-SPACES	length and room made available for the string (+1) in the work space.
		POP	HL	The starting address of the string goes to HL as a source address.
		LD	(CH-ADD),DE	The pointer to the first new
		PUSH	DE	space goes to CH-ADD and to the machine stack.
		LDIR		The string is copied to the work space, together with an extra byte.
		EX	DE,HL	Switch the pointers.
		DEC	HL	The extra byte is replaced by a
		LD	(HL),+0D	'carriage return' character.
		RES	7,(FLAGS)	The syntax flag is reset and the
		CALL	24FB,SCANNING	string is scanned for correct syntax.
		RST	0018,GET-CHAR	The character after the string is fetched.
		CP	+0D	A check is made that the end of the expression has been reached.
		JR	NZ,360C,V-RPORT-C	If not, the error is reported.
		POP	HL	The starting address of the string is fetched.
		POP	AF	The 'flag' for 'val/val$' is
		XOR	(FLAGS)	fetched and bit 6 is compared
		AND	+40	with bit 6 of the result of the syntax scan.
360C	V-RPORT-C	JP	NZ,1C8A,REPORT-C	Report the error if they do not match.
		LD	(CH-ADD),HL	Start address to CH-ADD again.
		SET	7,(FLAGS)	The flag is set for line execution.

```
                CALL    24FB,SCANNING   The string is treated as a 'next
                                        expression' and a 'last value'
                                        produced.
                POP     HL              The original value of CH-ADD is
                LD      (CH-ADD),HL     restored.
                JR      35BF,STK-PNTRS  The subroutine exits via STK-
                                        PNTRS which resets the pointers.
```

THE 'STR$' FUNCTION

(Offset 2E: 'str$')

This subroutine handles the function STR$ X and returns a 'last value' which is a set of parameters that define a string containing what would appear on the screen if X were displayed by a PRINT command.

```
361F    str$    LD      BC,+0001        One space is made in the work
                RST     0030,BC-SPACES  space and its address is copied
                LD      (K-CUR),HL      to K-CUR, the address of the
                                        cursor.
                PUSH    HL              This address is saved on the
                                        stack too.
                LD      HL,(CURCHL)     The current channel address is
                PUSH    HL              saved on the machine stack.
                LD      A,+FF           Channel 'R' is opened, allowing
                CALL    1601,CHAN-OPEN  the string to be 'printed' out
                                        into the work space.
                CALL    2DE3,PRINT-FP   The 'last value', X, is now
                                        printed out in the work space
                                        and the work space is expanded
                                        with each character.
                POP     HL              Restore CURCHL to HL and
                CALL    1615,CHAN-FLAG  restore the flags that are
                                        appropriate to it.
                POP     DE              Restore the start address of the
                                        string.
                LD      HL,(K-CUR)      Now the cursor address is one
                AND     A               past the end of the string and
                SBC     HL,DE           hence the difference is the
                                        length.
                LD      B,H             Transfer the length to BC.
                LD      C,L
                CALL    2AB2,STK-STO-$  Pass the parameters of the new
                                        string to the calculator stack.
                EX      DE,HL           Reset the pointers.
                RET                     Finished.
```

Note: See PRINT-FP for an explanation of the 'PRINT "A"+STR$ 0.1' error.

THE 'READ-IN' SUBROUTINE

(Offset 1A: 'read-in')

This subroutine is called via the calculator offset through the first line of the S-INKEY$ routine in SCANNING. It appears to provide for the reading in of data through different streams from those available on the standard Spectrum. Like INKEY$ the subroutine returns a string.

```
3645    read-in CALL    1E94,FIND-INT1  The numerical parameter is
                                        compressed into the A register.
                CP      +10             Is it smaller than 16 decimal?
                JP      NC,1E9F,REPORT-B If not, report the error.
                LD      HL,(CURCHL)     The current channel address is
                PUSH    HL              saved on the machine stack.
                CALL    1601,CHAN-OPEN  The channel specified by the
                                        parameter is opened.
```

		CALL	15E6,INPUT-AD	The signal is now accepted, like a 'key-value'.
		LD	BC,+0000	The default length of the resulting string is zero.
		JR	NC,365F,R-I-STORE	Jump if there was no signal.
		INC	C	Set the length to 1 now.
		RST	0030,BC-SPACES	Make a space in the work space.
		LD	(DE),A	Put the string into it.
365F	R-I-STORE	CALL	2AB2,STK-STO-$	Pass the parameters of the string to the calculator stack.
		POP	HL	Restore CURCHL and the
		CALL	1615,CHAN-FLAG	appropriate flags.
		JP	35BF,STK-PNTRS	Exit, setting the pointers.

THE 'CODE' FUNCTION

(Offset 1C: 'code')

This subroutine handles the function CODE A$ and returns the Spectrum code of the first character in A$, or zero if A$ should be null.

3669	code	CALL	2BF1,STK-FETCH	The parameters of the string are fetched.
		LD	A,B	The length is tested and the A
		OR	C	register holding zero is carried
		JR	Z,3671,STK-CODE	forward is A$ is a null string.
		LD	A,(DE)	The code of the first character is put into A otherwise.
3671	STK-CODE	JP	2D28,STACK-A	The subroutine exits via STACK-A which gives the correct 'last value'.

THE 'LEN' FUNCTION

(Offset 1E: 'len')

This subroutine handles the function LEN A$ and returns a 'last value' that is equal to the length of the string.

3674	len	CALL	2BF1,STK-FETCH	The parameters of the string are fetched.
		JP	2D2B,STACK-BC	The subroutine exits via STACK-BC which gives the correct 'last value'.

THE 'DECREASE THE COUNTER' SUBROUTINE

(Offset 35: 'dec-jr-nz')

This subroutine is only called by the SERIES GENERATOR subroutine and in effect is a 'DJNZ' operation but the counter is the system variable, BREG, rather than the B register.

367A	dec-jr-nz	EXX		Go to the alternative register set
		PUSH	HL	and save the next literal pointer on the machine stack.
		LD	HL,+5C67	Make HL point to BREG.
		DEC	(HL)	Decrease BREG.
		POP	HL	Restore the next literal pointer.
		JR	NZ,3687,JUMP-2	The jump is made on non-zero.
		INC	HL	The next literal is passed over.
		EXX		Return to the main register set.
		RET		Finished.

THE 'JUMP' SUBROUTINE

(Offset 33: 'jump')

This subroutine executes an unconditional jump when called by the literal '33'. It is also used by the subroutines DECREASE THE COUNTER and JUMP ON TRUE.

```
3686  JUMP      EXX                    Go to the next alternate register set.
3687  JUMP-2    LD        E,(HL)       The next literal (jump length) is
                                       put in the E' register.
                LD        A,E          The number 00 hex or FF hex
                RLA                    is formed in A according as E'
                SBC       A,A          is positive or negative, and is
                LD        D,A          then copied to D'.
                ADD       HL,DE        The registers H' & L' now hold
                EXX                    the next literal pointer.
                RET                    Finished.
```

THE 'JUMP ON TRUE' SUBROUTINE

(Offset 00: 'jump-true')

This subroutine executes a conditional jump if the 'last value' on the calculator stack, or more precisely the number addressed currently by the DE register pair, is true.

```
368F  jump-true INC       DE           Point to the third byte, which is
                INC       DE           zero or one.
                LD        A,(DE)       Collect this byte in the A
                                       register.
                DEC       DE           Point to the first byte once
                DEC       DE           again.
                AND       A            Test the third byte: is it zero?
                JR        NZ,3686,JUMP Make the jump if the byte is
                                       non-zero, i.e. if the number is
                                       not-false.
                EXX                    Go to the alternate register set.
                INC       HL           Pass over the jump length.
                EXX                    Back to the main set of
                                       registers.
                RET                    Finished.
```

THE 'END-CALC' SUBROUTINE

(Offset 38: 'end-calc')

This subroutine ends a RST 0028 operation.

```
369B  end-calc  POP       AF           The return address to the
                                       calculator ('RE-ENTRY') is
                                       discarded.
                EXX                    Instead, the address in H'L' is
                EX        (SP).HL      put on the machine stack and
                EXX                    an indirect jump is made to it.
                                       H'L' will now hold any earlier
                                       address in the calculator chain
                                       of addresses.
                RET                    Finished.
```

THE 'MODULUS' SUBROUTINE

(Offset 32: 'n-mod-m')

This subroutine calculates M (mod M), where M is a positive integer held at the top of the calculator stack, the 'last value', and N is the integer held on the stack beneath M.
The subroutine returns the integer quotient INT (N/M) at the top of the calculator stack, the 'last value', and the remainder N-INT (N/M) in the second place on the stack.
This subroutine is called during the calculation of a random number to reduce N mod 65537 decimal.

```
36A0  n-mod-m   RST       0028,FP-CALC N,M
                DEFB      +C0,st-mem-0 N,M       mem-0 holds M
                DEFB      +02,delete   N
                DEFB      +31,duplicate N, N
                DEFB      +E0,get-mem-0 N, N, M
                DEFB      +05,division N, N/M
                DEFB      +27,int      N, INT (N/M)
```

```
                DEFB    +E0,get-mem-0       N, INT (N/M),M
                DEFB    +01,exchange        N, M, INT (N/M)
                DEFB    +C0,st-mem-0        N, M, INT (N/M)     mem-0 holds
                                            INT (N/M)
                DEFB    +04,multiply        N, M*INT (N/M)
                DEFB    +03,subtract        n-M*INT (N/M)
                DEFB    +E0,get-mem-0       n-M*INT (N/M), INT (N/M)
                DEFB    +38,end-calc
                RET                         Finished.
```

THE 'INT' FUNCTION

(Offset 27: 'int')

This subroutine handles the function INT X and returns a 'last value' that is the 'integer part' of the value supplied. Thus INT 2.4 gives 2 but as the subroutine always rounds the result down INT -2.4 gives -3.
The subroutine uses the INTEGER TRUNCATION TOWARDS ZERO subroutine at 3214 to produce I (X) such that I (2.4) gives 2 and I (-2.4) gives -2. Thus, INT X is gives by I (X) for values of X that are greater than or equal to zero, and I (X)-1 for negative values of X that are not already integers, when the result is, of course, I (X).

```
36AF    int     RST     0028,FP-CALC        X
                DEFB    +31,duplicate       X, X
                DEFB    +36,less-0          X, (1/0)
                DEFB    +00,jump-true       X
                DEFB    +04, to 36B7,X-NEG  X
```

For values of X that have been shown to be greater than or equal to zero there is no jump and I (X) is readily found.

```
                DEFB    +3A,truncate        I (X)
                DEFB    +38,end-calc
                RET                         Finished.
```

when X is a negative integer I (X) is returned, otherwise I (X)-1 is returned.

```
36B7    X-NEG   DEFB    +31,duplicate       X, X
                DEFB    +3A,truncate        X, I (X)
                DEFB    +C0,st-mem-0        X, I (X)    mem-0 holds I (X)
                DEFB    +03,subtract        X-I (X)
                DEFB    +E0,get-mem-0       X-I (X), I (X)
                DEFB    +01,exchange        I (X), X-I (X)
                DEFB    +30,not             I (X), (1/0)
                DEFB    +00,jump-true       I (X)
                DEFB    +03,to 36C2,EXIT    I (X)
```

The jump is made for values of X that are negative integers, otherwise there is no jump and I (X)-1 is calculated.

```
                DEFB    +A1,stk-one         I (X), 1
                DEFB    +03,subtract        I (X)-1
```

In either case the subroutine finishes with;

```
36C2    EXIT    DEFB    +38,end-calc        I (X) or I (X)-1
        RET
```

THE 'EXPONENTIAL' FUNCTION

(Offset 26: 'exp')

This subroutine handles the function EXP X and is the first of four routines that use SERIES GENERATOR to produce Chebyshev polynomials.
The approximation to EXP X is found as follows:

i. X is divided by LN 2 to give Y, so that 2 to the power Y is now the required result.

ii. The value N is found, such that N=INT Y.

iii. The value W is found, such that W=Y-N, where 0 <=W <=1, as required for the series to converge.

iv. The argument Z if formed, such that Z=2*w-1.

v. The SERIES GENERATOR is used to return 2**W.

vi. Finally N is added to the exponent, giving 2**(N+W), which is 2**Y and therefore the required answer for EXP X.

The method is illustrated using a BASIC program in the Appendix.

```
36C4    EXP         RST         0028,FP-CALC            X
Perform step i.

                    DEFB        +3D,re-stack            X (in full floating-point form)
                    DEFB        +34,stk-data            X, 1/LN 2
                    DEFB        +F1,exponent+81
                    DEFB        +38,+AA,+3B,+29
                    DEFB        +04,multiply            X/LN 2 = Y

Perform step ii.

                    DEFB        +31,duplicate           Y, Y
                    DEFB        +27,int,1C46            Y, INT Y = N
                    DEFB        +C3,st-mem-3            Y, N        mem-3 holds N

Perform step iii.

                    DEFB        +03,subtract            Y-N = W

Perform step iv.

                    DEFB        +31,duplicate           W, W
                    DEFB        +0F,addition            2*W
                    DEFB        +A1,stk-one             2*W, 1
                    DEFB        +03,subtract            2*W-1 = Z

Perform step v, passing to the SERIES GENERATOR the parameter '8' and the eight constants required.

                    DEFB        +88,series-08           Z
      1.            DEFB        +13,exponent+63
                    DEFB        +36,(+00,+00,+00)
      2.            DEFB        +58,exponent+68
                    DEFB        +65,+66,(+00,+00)
      3.            DEFB        +9D,exponent+6D
                    DEFB        +78,+65,+40,(+00)
      4.            DEFB        +A2,exponent+72
                    DEFB        +60,+32,+C9,(+00)
      5.            DEFB        +E7,exponent+77
                    DEFB        +21,+F7,+AF,+24
      6.            DEFB        +EB,exponent+7B
                    DEFB        +2F,+B0,+B0,+14
      7.            DEFB        +EE,exponent +7E
                    DEFB        +7E,+BB,+94,+58
      8.            DEFB        +F1,exponent+81
                    DEFB        +3A,+7E,+F8,+CF

At the end of the last loop the 'last value' is 2**W.

Perform step vi.

                    DEFB        +E3,get-mem-3           2**W, N
                    DEFB        +38,end-calc
                    CALL        2DD5,FP-TO-A            The absolute value of N mod
                                                        256 decimal, is put into the A
                                                        register.
                    JR          NZ,3705,N-NEGTV         Jump forward if N was negative.
                    JR          C,3703,REPORT-6         Error if ABS N greater than 255
                                                        dec.
                    ADD         A,(HL)                  Now add ABS N to the
                                                        exponent.
                    JR          NC,370C,RESULT-OK       Jump unless e greater than 255
                                                        dec.
```

Report 6 - Number too big

3703	REPORT-6	RST	0008,ERROR-1	Call the error handling
		DEFB	+05	routine.
3705	N-NEGTV	JR	C,370E,RSLT-ZERO	The result is to be zero if N is less than -255 decimal.
		SUB	(HL)	Subtract ABS N from the exponent as N was negative.
		JR	NC,370E,RSLT-ZERO	Zero result if e less than zero.
		NEG		Minus e is changed to e.
370C	RESULT-OK	LD	(HL),A	The exponent, e, is entered.
		RET		
370E	RSLT-ZERO	RST	0028,FP-CALC	Use the calculator to make the
		DEFB	+02,delete	'last value' zero.
		DEFB	+A0,stk-zero	
		DEFB	+38,end-calc	
		RET		Finished, with EXP X = 0.

THE 'NATURAL LOGARITHM' FUNCTION

(Offset 25: 'ln')

This subroutine handles the function LN X and is the second of the four routines that use SERIES GENERATOR to produce Chebyshev polynomials.
The approximation to LN X is found as follows:

I. X is tested and report A is given if X is not positive.
II. X is then split into its true exponent, e', and its mantissa X' = X/(2**e'), where X' is greater than, or equal to, 0.5 but still less than 1.
III. The required value Y1 or Y2 is formed. If X' is greater than 0.8 then Y1=e'*LN 2 and if otherwise Y2 = (e'-1)*LN 2.
IV. If X' is greater than 0.8 then the quantity X'-1 is stacked; otherwise 2*X'-1 is stacked.
V. Now the argument Z is formed, being if X' is greater than 0.8, Z = 2.5*X'-3; otherwise Z = 5*X'-3. In each case, -1 <=Z <=1, as required for the series to converge.
VI. The SERIES GENERATOR is used to produce the required function.
VII. Finally a simply multiplication and addition leads to LN X being returned as the 'last value'.

3713	ln	RST	0028,FP-CALC	X

Perform step i.

	DEFB	+3D,re-stack	X (in full floating-point form)
	DEFB	+31,duplicate	X, X
	DEFB	+37,greater-0	X, (1/0)
	DEFB	+00,jump-true	X
	DEFB	+04,to 371C, VALID	X
	DEFB	+38,end-calc	X

Report A - Invalid argument

371A	REPORT-A	RST	0008,ERROR-1	Call the error handling
		DEFB	+09	routine.

Perform step ii.

371C	VALID	DEFB	+A0,stk-zero	X,0 The deleted 1 is
		DEFB	+02,delete	X overwritten with zero.
		DEFB	+38,end-calc	X
		LD	A,(HL)	The exponent, e, goes into A.
		LD	(HL),+80	X is reduced to X'.
		CALL	2D28,STACK-A	The stack holds: X', e.
		RST	0028,FP-CALC	X', e
		DEFB	+34,stk-data	X', e, 128 (decimal)
		DEFB	+38,exponent+88	

```
                DEFB    +00,(+00,+00,+00)
                DEFB    +03,subtract        X', e'
```

Perform step iii.

```
                DEFB    +01,exchange        e', X'
                DEFB    +31,duplicate       e', X', X'
                DEFB    +34,stk-data        e', X', X',0.8 (decimal)
                DEFB    +F0,exponent+80
                DEFB    +4C,+CC,+CC,+CD
                DEFB    +03,subtract        e', X', X'-0.8
                DEFB    +37,greater-0       e', X', (1/0)
                DEFB    +00,jump-true       e', X'
                DEFB    +08,to 373D, GRE.8  e', X'
                DEFB    +01,exchange        X', e'
                DEFB    +A1,stk-one         X', e', 1
                DEFB    +03,subtract        X', e'-1
                DEFB    +01,exchange        e'-1, X'
                DEFB    +38,end-calc        e'-1, X'
                INC     (HL)                Double X' to give 2*X'.
                RST     0028,FP-CALC        e'-1,2*X'
373D    GRE.8   DEFB    +01,exchange        X',e'       - X' large.
                                            2*X',e'-1   - X' small.
                DEFB    +34,stk-data        X',e',LN 2
                DEFB    +F0,exponent+80     2*X',e'-1, LN 2
                DEFB    +31,+72,+17,+F8
                DEFB    +04,multiply        X',e'*LN 2 = Y1
                                            2*X', (e'-1)*LN 2 = Y2
```

Perform step iv.

```
                DEFB    +01,exchange        Y1, X'      - X' large.
                                            Y2, 2*X'    - X' small.
                DEFB    +A2,stk-half        Y1, X', .5 (decimal)
                                            Y2, 2*X', .5
                DEFB    +03,subtract        Y1, X'-.5
                                            Y2, 2*X'-.5
                DEFB    +A2,stk-half        Y1, X'-.5, .5
                                            Y2, 2*X'-.5, .5
                DEFB    +03,subtract        Y1, X'-1
                                            Y2, 2*X'-1
```

Perform step v.

```
                DEFB    +31,duplicate       Y, X'-1, X'-1
                                            Y2, 2*X'-1, 2*X'-1
                DEFB    +34,stk-data        Y1, X'-1, X'-1, 2.5 (decimal)
                                            Y2, 2*X'-1, 2*X'-1, 2.5
                DEFB    +32,exponent+82
                DEFB    +20,(+00,+00,+00)
                DEFB    +04,multiply        Y1, X'-1,2.5*X'-3 = Z
                                            Y2, 2*X'-1, 5*X'-3 = Z
```

Perform step vi, passing to the SERIES GENERATOR the parameter '12' decimal, and the twelve constant required.

```
                DEFB    +8C,series-0C       Y1, X'-1, Z or Y2, 2*X'-1, Z
        1.      DEFB    +11,exponent+61
                DEFB    +AC,(+00,+00,+00)
        2.      DEFB    +14,exponent+64
                DEFB    +09,(+00,+00,+00)
        3.      DEFB    +56,exponent+66
                DEFB    +DA,+A5,(+00,+00)
```

```
4.      DEFB    +59,exponent+69
        DEFB    +30,+C5,(+00,+00)
5.      DEFB    +5C,exponent+6C
        DEFB    +90,+AA,(+00,+00)
6.      DEFB    +9E,exponent+6E
        DEFB    +70,+6F,+61,(+00)
7.      DEFB    +A1,exponent+71
        DEFB    +CB,+DA,+96,(+00)
8.      DEFB    +A4,exponent+74
        DEFB    +31,+9F,+B4,(+00)
9.      DEFB    +E7,exponent+77
        DEFB    +A0,+FE,+5C,+FC
10.     DEFB    +EA,exponent+7A
        DEFB    +1B,+43,+CA,+36
11.     DEFB    +ED,exponent+7D
        DEFB    +A7,+9C,+7E,+5E
12.     DEFB    +F0,exponent+80
        DEFB    +6E,+23,+80,+93
```

At the end of the last loop the 'last value' is:

```
either  LN X'/(X'-1) for the larger values of X'
or      LN (2*X')/(2*X'-1) for the smaller values of X'.
```

Perform step vii.

```
DEFB    +04,multiply    Y1=LN (2**e'), LN X'
                        Y2=LN (2**(e'-1)), LN (2*X')
DEFB    +0F,addition    LN (2**e')*X')              = LN X
                        LN (2**(e'-1)*2*X')         = LN X
DEFB    +38,end-calc    LN X
RET                     Finished: 'last value' is LN X.
```

THE 'REDUCE ARGUMENT' SUBROUTINE

(Offset 39: 'get-argt')

This subroutine transforms the argument X of SIN X or COS X into a value V.
The subroutine first finds a value Y such that:

Y = X/(2*PI) - INT (X/2*PI) + 0.5), where Y is greater than, or equal to, -.5 but less than +.5.
The subroutine returns with:

```
V = 4*Y    if -1 <=4*Y <=1- case i.
or, V = 2-4*Y          if 1 <4*Y <2     - case ii.
or, V = -4*Y-2         if -2 <=4*Y < -1.                - case iii.
```

In each case, -1 < =V <=1 and SIN (PI*V/2) = SIN X

```
3783    get-argt    RST     0028,FP-CALC        X
                    DEFB    +3D,re-stack        X (in full floating-point form)
                    DEFB    +34,stk-data        X, 1/(2*PI)
                    DEFB    +EE,exponent+7E
                    DEFB    +22,+F9,+83,+6E
                    DEFB    +04,multiply        X/(2*PI)
                    DEFB    +31,duplicate       X/(2*PI), X/(2*PI)
                    DEFB    +A2,stk-half        X/(2*PI), X/(2*PI), 0.5
                    DEFB    +0F,addition        X/(2*PI), X/(2*PI)+0.5
                    DEFB    +27,int,1C46        X/(2*PI), INT (X/(2*PI)+0.5)
                    DEFB    +03,subtract,174C   X/(2*PI)-INT (X/(2*PI)+0.5)=Y
```

Note: Adding 0.5 and taking INT rounds the result to the nearest integer.

```
                DEFB    +31,duplicate           Y, Y
                DEFB    +0F,addition            2*Y
                DEFB    +31,duplicate           2*Y, 2*Y
                DEFB    +0F,addition            4*Y
                DEFB    +31,duplicate           4*Y, 4*Y
                DEFB    +2A,abs                 4*Y, ABS (4*Y)
                DEFB    +A1,stk-one             4*Y, ABS (4*Y), 1
                DEFB    +03,subtract            4*Y, ABS (4*Y)-1 = Z
                DEFB    +31,duplicate           4*Y, Z, Z
                DEFB    +37,greater-0           4*Y, Z, (1/0)
                DEFB    +C0,st-mem-0            Mem-0 holds the result of the
                                                test.
                DEFB    +00,jump-true           4*Y, Z
                DEFB    +04, to 37A1,ZPLUS      4*Y, Z
                DEFB    +02,delete              4*Y
                DEFB    +38,end-calc            4*Y = V - case i.
                RET                             Finished.
```

If the jump was made then continue.

```
37A1    ZPLUS   DEFB    +A1,stk-one             4*Y, Z, 1
                DEFB    +03,subtract            4*Y, Z-1
                DEFB    +01,exchange            Z-1,4*Y
                DEFB    +36,less-0              Z-1,(1/0)
                DEFB    +00,jump-true           Z-1
                DEFB    +02,to 37A8,YNEG        Z-1
                DEFB    +1B,negate              1-Z
37A8    YNEG    DEFB    +38,end-calc            1-Z = V - case ii.
                                                Z-1 = V - case iii.
                RET                             Finished.
```

THE 'COSINE' FUNCTION

(Offset 20: 'cos')

This subroutine handles the function COS X and returns a 'last value' 'that is an approximation to COS X.
The subroutine uses the expression:
COS X = SIN (PI*W/2), where -1 <=W <=1.
In deriving W for X the subroutine uses the test result obtained in the previous subroutine and stored for this purpose in mem-0. It then jumps to the SINE, subroutine, entering at C-ENT, to produce a 'last value' of COS X.

```
37AA    cos     RST     0028,FP-CALC.           X
                DEFB    +39,get-argt            V
                DEFB    +2A,abs                 ABS V
                DEFB    +A1,stk-one             ABS V, 1
                DEFB    +03,subtract            ABS V-1
                DEFB    +E0,get-mem-0           ABS V-1, (1/0)
                DEFB    +00,jump-true           ABS V-1
                DEFB    +06, to 37B7,C-ENT      ABS V-1 = W
```

If the jump was not made then continue.

```
                DEFB    +1B,negate              1-ABS V
                DEFB    +33,jump                1-ABS V
                DEFB    +03, to 37B7,C-ENT      1-ABS V = W
```

THE 'SINE' FUNCTION

(Offset 1F: 'sin')

This subroutine handles the function SIN X and is the third of the four routines that use SERIES GENERATOR to produce Chebyshev polynomials.
The approximation to SIN X is found as follows:

i. The argument X is reduced and in this case W = V directly.

Note that -1 <=W <=1, as required for the series to converge.
ii. The argument Z is formed, such that Z=2*W*W-1.
iii. The SERIES GENERATOR is used to return (SIN (PI*W/2))/W
iv. Finally a simple multiplication gives SIN X.

```
37B5    sin         RST     0028 FP-CALC        X
```

Perform step i.

```
                    DEFB    +39,get-argt        W
```

Perform step ii. The subroutine from now on is common to both the SINE and COSINE functions.

```
37B7    C-ENT       DEFB    +31,duplicate       W, W
                    DEFB    +31,duplicate       W, W, W
                    DEFB    +04,multiply        W, W*W
                    DEFB    +31,duplicate       W, W*W, W*W
                    DEFB    +0F,addition        W, 2*W*W
                    DEFB    +A1,stk-one         W, 2*W*W, 1
                    DEFB    +03,subtract        W, 2*W*W-1 = Z
```

Perform step iii, passing to the SERIES GENERATOR the parameter '6' and the six constants required.

```
                    DEFB    +86,series-06       W, Z
        1.          DEFB    +14,exponent+64
                    DEFB    +E6,(+00,+00,+00)
        2.          DEFB    +5C,exponent+6C
                    DEFB    +1F,+0B,(+00,+00)
        3.          DEFB    +A3,exponent+73
                    DEFB    +8F,+38,+EE,(+00)
        4.          DEFB    +E9,exponent+79
                    DEFB    +15,+63,+BB,+23
        5.          DEFB    +EE,exponent+7E
                    DEFB    +92,+0D,+CD,+ED
        6.          DEFB    +F1,exponent+81
                    DEFB    +23,+5D,+1B,+EA
```

At the end of the last loop the 'last value' is (SIN (PI*W/2))/W.

Perform step v.

```
                    DEFB    +04,multiply        SIN (PI*W/2) = SIN X (or =
                                                COS X)
                    DEFB    +38,end-calc
                    RET                         Finished: 'last value' = SIN X.
                                                or ('last value' = COS X)
```

THE 'TAN' FUNCTION

(Offset 21: 'tan')

This subroutine handles the function TAN X. The subroutine simply returns SIN X/COS X, with arithmetic overflow if COS X = 0.

```
37DA    tan         RST     0028,FP-CALC        X
                    DEFB    +31,duplicate       X, X
                    DEFB    +1F,sin             X, SIN X
                    DEFB    +01,exchange        SIN X, X
                    DEFB    +20,cos             SIN X,COS X
                    DEFB    +05,division        SIN X/COS X = TAN X
                                                Report arithmetic overflow if
                                                needed.
                    DEFB    +38,end-calc        TAN X
                    RET                         Finished: 'last value' = TAN X.
```

THE 'ARCTAN' FUNCTION

(Offset 24: 'atn')

This subroutine handles the function ATN X and is the last of the four routines that use SERIES GENERATOR to produce Chebyshev polynomials. It returns a real number between -PI/2 and PI/2, which is equal to the value in radians of the angle whose tan is X. The approximation to ATN X is found as follows:

i. The values W and Y are found for three cases of X, such that:

```
if -1 < X < 1          then W = 0      & Y = X          - case i.
if -1 < =X  then W = PI/2  & Y = -1/X  - case ii.
if X < =-1  then W = -PI/2 & Y = -1/X  - case iii.
```

In each case, -1 < =Y < =1, as required for the series to converge.

ii. The argument Z is formed, such that:

```
if -1 < X < 1          then Z = 2*Y*Y-1 = 2*X*X-1      - case i.
if 1 < X    then Z = 2*Y*Y-1 = 2/(X*X)-1  - case ii.
if X < =-1  then Z = 2*Y*Y-1 = 2/(X*X)-1  - case iii.
```

iii. The SERIES GENERATOR is used to produce the required function.

iv. Finally a simple multiplication and addition give ATN X.

Perform stage i.

```
37E2    atn       CALL    3297,RE-STACK      Use the full floating-point form
                                             of X.
                  LD      A,(HL)             Fetch the exponent of X.
                  CP      +81
                  JR      C,37F8,SMALL       Jump forward for case i: Y = X.
                  RST     0028,FP-CALC       X
                  DEFB    +A1,stk-one        X, 1
                  DEFB    +1B,negate         X,-1
                  DEFB    +01,exchange       -1, X
                  DEFB    +05,division       -1/X
                  DEFB    +31,duplicate      -1/X, -1/X
                  DEFB    +36,less-0         -1/X, (1/0)
                  DEFB    +A3,stk-pi/2       -1/X, (1/0), PI/2
                  DEFB    +01,exchange       -1/X, PI/2, (1/0)
                  DEFB    +00,jump-true      -1/X, PI/2
                  DEFB    +06, to 37FA,CASES Jump forward for case ii:
                                             Y = -1/X  W = PI/2
                  DEFB    +1B,negate         -1/X, -PI/2
                  DEFB    +33,jump           -1/X, -PI/2
                  DEFB    +03,to 37FA,CASES  Jump forward for case iii:
                                             Y = -1/X  W = -PI/2
37F8    SMALL     RST     0028,FP-CALC       Y
                  DEFB    +A0,stk-zero       Y, 0
                                             Continue for case i: W = 0
```

Perform step ii.

```
37FA    CASES     DEFB    +01,exchange       W, Y
                  DEFB    +31,duplicate      W, Y, Y
                  DEFB    +31,duplicate      W, Y, Y, Y
                  DEFB    +04,multiply       W, Y, Y*Y
                  DEFB    +31,duplicate      W, Y, Y*Y, Y*Y
                  DEFB    +0F,addition       W, Y, 2*Y*Y
                  DEFB    +A1,stk-one        W, Y, 2*Y*Y, 1
                  DEFB    +03,subtract       W, Y, 2*Y*Y-1 = Z
```

Perform step iii, passing to the SERIES GENERATOR the parameter '12' decimal, and the twelve constants required.

```
                  DEFB    +8C,series-0C      W, Y, Z
          1.      DEFB    +10,exponent+60
                  DEFB    +B2,(+00,+00,+00)
```

```
2.      DEFB    +13,exponent+63
        DEFB    +0E,(+00,+00,+00)
3.      DEFB    +55,exponent+65
        DEFB    +E4,+8D,(+00,+00)
4.      DEFB    +58,exponent+68
        DEFB    +39,+BC,(+00,+00)
5.      DEFB    +5B,exponent+6B
        DEFB    +98,+FD,(+00,+00)
6.      DEFB    +9E,exponent+6E
        DEFB    +00,+36,+75,(+00)
7.      DEFB    +A0,exponent+70
        DEFB    +DB,+E8,+B4,(+00)
8.      DEFB    +63,exponent+73
        DEFB    +42,+C4,(+00,+00)
9.      DEFB    +E6,exponent+76
        DEFB    +B5,+09,+36,+BE
10.     DEFB    +E9,exponent+79
        DEFB    +36,+73,+1B,+5D
11.     DEFB    +EC,exponent+7C
        DEFB    +D8,+DE,+63,+BE
12.     DEFB    +F0,exponent+80
        DEFB    +61,+A1,+B3,+0C
```

At the end of the last loop the 'last value' is:

```
ATN X/X         - case i.
ATN (-1/X)/(-1/X)       - case ii.
ATN (-1/X)/(-1/X)       - case iii.
```

Perform step iv.

```
        DEFB    +04,multiply        W, ATN X- case i.
                                    W, ATN (-1/X)       - case ii.
                                    W, ATN (-1/X)       - case iii.
        DEFB    +0F,addition        ATN X - all cases now.
        DEFB    +38,end-calc
        RET                         Finished: 'last value' = ATN X.
```

THE 'ARCSIN' FUNCTION

(Offset 22: 'asn')

This subroutine handles the function ASN X and return a real real number from -PI/2 to PI/2 inclusive which is equal to the value in radians of the angle whose sine is X. Thereby if Y = ASN X then X = SIN Y.
This subroutine uses the trigonometric identity:
TAN (Y/2) = SIN Y/1(1+COS Y)
to obtain TAN (Y/2) and hence (using ATN) Y/2 and finally Y.

```
3833    asn     RST     0028,FP-CALC        X
                DEFB    +31,duplicate       X, X
                DEFB    +31,duplicate       X, X, X
                DEFB    +04,multiply        X, X*X
                DEFB    +A1,stk-one         X, X*X, 1
                DEFB    +03,subtract        X, X*X-1
                DEFB    +1B,negate          X,1-X*X
                DEFB    +28,sqr             X,SQR (1-X*X)
                DEFB    +A1,stk-one         X,SQR (1-X*X), 1
                DEFB    +0F,addition        X, 1+SQR (1-X*X)
                DEFB    +05,division        X/(1+SQR (1-X*X)) = TAN
                                            (Y/2)
                DEFB    +24,atn             Y/2
                DEFB    +31,duplicate       Y/2, Y/2
                DEFB    +0F,addition        Y = ASN X
                DEFB    +38,end-calc
                RET                         Finished: 'last value' = ASN X.
```

THE 'ARCCOS' FUNCTION
(Offset 23: 'acs')

This subroutine handles the function ACS X and returns a real number from zero to PI inclusive which is equal to the value in radians of the angle whose cosine is X.

This subroutine uses the relation:

ACS X = PI/2 - ASN X

```
3843    acs     RST     0028,FP-CALC    X
                DEFB    +22,asn         ASN X
                DEFB    +A3,stk-pi/2    ASN X,PI/2
                DEFN    +03,subtract    ASN X-PI/2
                DEFB    +1B,negate      PI/2-ASN X = ACS X
                DEFB    +38,end-calc
                RET                     Finished: 'last value' = ACS X.
```

THE 'SQUARE ROOT' FUNCTION
(Offset 28: 'sqr')

This subroutine handles the function SQR X and returns the positive square root of the real number X if X is positive, and zero if X is zero. A negative value of X gives rise to report A - invalid argument (via In in the EXPONENTIATION subroutine).

This subroutine treats the square root operation as being X**.5 and therefore stacks the value .5 and proceeds directly into the EXPONENTIATION subroutine.

```
384A    sqr     RST     0028,FP-CALC    X
                DEFB    +31,duplicate   X,X
                DEFB    +30,not         X,(1/0)
                DEFB    +00,jump-true   X
                DEFB    +1E,to 386C,LAST X
```

The jump is made if X = 0, otherwise continue with:

```
                DEFB    +A2,stk-half    X,.5
                DEFB    +38,end-calc
```

and then find the result of X**.5.

THE 'EXPONENTIATION' OPERATION
(Offset 06: 'to-power')

This subroutine performs the binary operation of raising the first number, X, to the power of the second number, Y.

The subroutine treats the result X**Y as being equivalent to EXP (Y*LN X). It returns this value unless X is zero, in which case it returns 1 if Y is also zero (0**0=1), returns zero if Y is positive and reports arithmetic overflow if Y is negative.

```
3851    to-power RST    0028,FP-CALC    X,Y
                DEFB    +01,exchange    Y,X
                DEFB    +31,duplicate   Y,X,X
                DEFB    +30,not         Y,X,(1/0)
                DEFB    +00,jump-true   Y,X
                DEFB    +07,to 385D,XIS0 Y,X
```

The jump is made if X = 0, otherwise EXP (Y*LN X) is formed.

```
                DEFB    +25,ln          Y,LN X
```

Giving report A if X is negative.

```
                DEFB    +04,multiply    Y*LN X
                DEFB    +38,end-calc
                JP      36C4,EXP        Exit via EXP to form EXP
                                        (Y*LN X).
```

The value of X is zero so consider the three possible cases involved.

```
385D    XIS0    DEFB    +02,delete      Y
                DEFB    +31,duplicate   Y,Y
                DEFB    +30,not         Y,(1/0)
                DEFB    +00,jump-true   Y
```

```
                DEFB    +09,to 386A,ONE     Y
```

The jump is made if X = 0 and Y = 0, otherwise proceed.

```
                DEFB    +A0,stk-zero        Y,0
                DEFB    +01,exchange        0,Y
                DEFB    +37,greater-0       0,(1/0)
                DEFB    +00,jump-true       0
                DEFB    +06,to 386C,LAST    0
```

The jump is made if X = 0 and Y is positive, otherwise proceed.

```
                DEFB    +A1,stk-one         0,1
                DEFB    +01,exchange        1,0
                DEFB    +05,division        Exit via 'division' as dividing by
                                            zero gives 'arithmetic overflow'.
```

The result is to be 1 for the operation.

```
386A    ONE     DEFB +02,delete             -
                DEFB +A1,stk-one            1
```

Now return with the 'last value' on the stack being 0**Y.

```
386C    LAST    DEFB +38,end-calc           (1/0)
                RET                         Finished: 'last value' is 0 or 1.
```

386E - 3CFF These locations are 'spare'. They all hold +FF.

3D00 - 3FFF These locations hold the 'character set'. There are 8 byte representations for all the characters with codes +20 (space) to +7F (©).

e.g. the letter 'A' has the representation 00 3C 42 42 7E 42 42 00 and thereby the form:

```
00000000
00111100
01000010
01000010
01111110
01000010
01000010
00000000
```

APPENDIX

BASIC PROGRAMS FOR THE MAIN SERIES

The following BASIC programs have been included as they give a good illustration of how Chebyshev polynomials are used to produce the approximations to the functions SIN, EXP, LN and ATN.

The series generator:

This subroutine is called by all the 'function' programs.

```
500  REM SERIES GENERATOR, ENTER
510  REM USING THE COUNTER BREG
520  REM AND ARRAY-A HOLDING THE
530  REM CONSTANTS.
540  REM FIRST VALUE IN Z.
550  LET M0=2*Z
560  LET M2=0
570  LET T=0
580  FOR I=BREG TO 1 STEP -1
590  LET M1=M2
600  LET U=T*M0-M2+A(BREG+1-I)
610  LET M2=T
620  LET T=U
630  NEXT I
640  LET T=T-M1
650  RETURN
660  REM LAST VALUE IN T.
```

In the above subroutine the variable are:

Z -	the entry value.
T -	the exit value.
M0 -	mem-0
M1 -	mem-1
M2 -	mem-2
I -	the counter for BREG.
U -	a temporary variable for T.
A(1) to A(BREG) -	the constants.
BREG -	the number of constants to be used.

To see how the Chebyshev polynomials are generated, record on paper the values of U, M1, M2 and T through the lines 550 to 630, passing, say, 6 times through the loop, and keeping the algebraic expressions for A(1) to A(6) without substituting numerical values. Then record T-M1. The multipliers of the constants A(1) to A(6) will then be the required Chebyshev polynomials. More precisely, the multiplier of A(1) will be 2*T5(Z), for A(2) it will be 2*T4(Z) and so on to 2*T1(Z) for A(5) and finally T0(Z) for A(6).

Note that T0(Z)=1, T1(Z)=Z and, for n>=2, Tn(Z)=2*Z*Tn-1(Z)-Tn-2(Z).

SIN X

```
 10  REM DEMONSTRATION FOR SIN X
 20  REM USING THE 'SERIES GENERATOR'.
 30  DIM A(6)
 40  LET A(1)=-.000000003
 50  LET A(2)=0.000000592
 60  LET A(3)=-.000068294
 70  LET A(4)=0.004559008
 80  LET A(5)=-.142630785
 90  LET A(6)=1.276278962
100  PRINT
110  PRINT "ENTER START VALUE IN DEGREES"
120  INPUT C
130  CLS
140  LET C=C-10
150  PRINT "BASIC PROGRAM","ROM PROGRAM"
160  PRINT "-------------","-----------"
170  PRINT
180  FOR J=1 TO 4
190  LET C=C+10
200  LET Y=C/360-INT (C/360+.5)
210  LET W=4*Y
220  IF W > 1 THEN LET W=2-W
230  IF W < -1 THEN LET W=-W-2
240  LET Z=2*W*W-1
250  LET BREG=6
260  REM USE 'SERIES GENERATOR'
270  GO SUB 550
280  PRINT TAB 6; "SIN ";C;" DEGREES"
290  PRINT
300  PRINT T*W,SIN (PI*C/180)
310  PRINT
320  NEXT J
330  GO TO 100
```

NOTES:

I. When C is entered this program calculates and prints SIN C degrees, SIN (C+10) degrees, SIN (C+20) degrees and SIN (C+30) degrees. It also prints the values obtained by using the ROM program. For a specimen of results, try entering these values in degrees: 0; 5; 100; -80; -260; 3600; -7200.

II. The constants A(1) to A(6) in lines 40 to 90 are given (apart from a factor of 1/2) in Abramowitz and Stegun Handbook of Mathematical Functions (Dover 1965) page 76. They can be checked by integrating (SIN (PI*X/2))/X over the interval U=0 to PI, after first multiplying by COS (N*U) for each constant (i.e. N=1,2,...,6) and substituting COS U=2*X*X-1. Each result should then be divided by PI. (This integration can be performed by approximate methods e.g. using Simpson's Rule if there is a reasonable computer or programmable calculator to hand.)

EXP X

```
 10  REM DEMONSTRATION FOR EXP X
 20  REM USING THE 'SERIES GENERATOR'
 30  LET T=0                    (This makes T the first variable.)
 40  DIM A(8)
 50  LET A(1)=0.000000001
 60  LET A(2)=0.000000053
 70  LET A(3)=0.000001851
 80  LET A(4)=0.000053453
 90  LET A(5)=0.001235714
100  LET A(6)=0.021446556
110  LET A(7)=0.248762434
120  LET A(8)=1.456999875
130  PRINT
140  PRINT "ENTER START VALUE"
150  INPUT C
160  CLS
170  LET C=C-10
180  PRINT "BASIC PROGRAM", "ROM PROGRAM"
190  PRINT "-------------", "-----------"
200  PRINT
210  FOR J=1 TO 4
220  LET C=C+10
230  LET D=C*1.442695041   (D=C*(1/LN 2);EXP C=2**D).
240  LET N=INT D
250  LET Z=D-N             (2**(N+Z) is now required).
260  LET Z=2*Z-1
270  LET BREG=8
280  REM USE "SERIES GENERATOR"
290  GO SUB 550
300  LET V=PEEK 23627+256*PEEK 23628+1          (V=(VARS)+1)
310  LET N=N+PEEK V
320  IF N > 255 THEN STOP  (STOP with arithmetic overflow).
330  IF N < 0 THEN GO TO 360
340  POKE V,N
350  GO TO 370
360  LET T=0
370  PRINT TAB 11;"EXP ";C
380  PRINT
390  PRINT T,EXP C
400  PRINT
410  NEXT J
420  GO TO 130
```

NOTES:

I. When C is entered this program calculates and prints EXP C, EXP (C+10), EXP (C+20) and EXP (C+30). It also prints the values obtained by using the ROM program. For a specimen of results, try entering these values: 0; 15; 65 (with overflow at the end); -100; -40.

II. The exponent is tested for overflow and for a zero result in lines 320 and 330. These tests are simpler in BASIC than in machine code, since the variable N, unlike the A register, is not confined to one byte.

III. The constants A(1) to A(8) in lines 50 to 120 can be obtained by integrating 2**X over the interval U=0 to PI, after first multiplying the COS (N*U) for each constant (i.e. for N=1,2,...,8) and substituting COS U = 2*X-1. Each result should then be divided by PI.

LN X:

```
 10  REM DEMONSTRATION FOR LN X
 20  REM USING THE 'SERIES GENERATOR'
 30  LET D=0                    (This makes D the first variable).
 40  DIM A(12)
 50  LET A(1)= -.0000000003
 60  LET A(2)=0.0000000020
 70  LET A(3)= -.0000000127
 80  LET A(4)=-0.0000000823
 90  LET A(5)= -.0000005389
100  LET A(6)=0.0000035828
110  LET A(7)= -.0000243013
120  LET A(8)=0.0001693953
130  LET A(9)= -.0012282837
140  LET A(10)=0.0094766116
150  LET A(11)= -.0818414567
160  LET A(12)=0.9302292213
170  PRINT
180  PRINT "ENTER START VALUE"
190  INPUT C
200  CLS
210  PRINT "BASIC PROGRAM", "ROM PROGRAM"
220  PRINT "-------------", "-----------"
230  PRINT
240  LET C=SQR C
250  FOR J=1 TO 4
260  LET C=C*C
270  IF C=0 THEN STOP       (STOP with 'invalid argument'.)
280  LET D=C
290  LET V=PEEK 23627+256*PEEK 23628+1
300  LET N=PEEK V-128       (N holds e').
310  POKE V,128
320  IF D<=0.8 THEN GO TO 360                    (D holds X').
330  LET S=D-1
340  LET Z=2.5*D-3
350  GO TO 390
360  LET N=N-1
370  LET S=2*D-1
380  LET Z=5*D-3
390  LET R=N*0.6931471806 (R holds N*LN 2).
400  LET BREG=12
410  REM USE 'SERIES GENERATOR'
420  GO SUB 550
430  PRINT TAB 8;"LN ";C
440  PRINT
450  PRINT S*T+R,LN C
460  PRINT
470  NEXT J
480  GO TO 170
```

NOTES:

I. When C is entered this program calculates and prints LN C, LN (C**2), LN (C**4) and LN (C**8). It also prints the values obtained by using the ROM program. For a specimen of results, try entering these values: 1.1; 0.9; 300; 0.004; 1E5 (for overflow) and 1E-5 (STOP as 'invalid argument').

II. The constants A(1) to A(12) in lines 50 to 160 can be obtained by integrating 5*LN (4* (X+1)/5)/(4*X-1) over the interval U=0 to PI, after first multiplying by COS (N*U) for each constant (i.e. for N=1,2,...,12) and substituting COS U=2*X-1. Each result should then be divided by PI.

ATN X:

```
 10  REM DEMONSTRATION FOR ATN X
 20  REM USING THE 'SERIES GENERATOR'
 30  DIM A(12)
 40  LET A(1)= -.0000000002
 50  LET A(2)=0.0000000010
 60  LET A(3)= -.0000000066
 70  LET A(4)=0.0000000432
 80  LET A(5)= -.0000002850
 90  LET A(6)=0.0000019105
100  LET A(7)= -.0000131076
110  LET A(8)=0.0000928715
120  LET A(9)= -.0006905975
130  LET A(10)=0.0055679210
140  LET A(11)= -.0529464623
150  LET A(12)=0.8813735870
160  PRINT
170  PRINT "ENTER START VALUE"
180  INPUT C
190  CLS
200  PRINT "BASIC PROGRAM", "ROM PROGRAM"
210  PRINT "-------------", "-----------"
220  PRINT
230  FOR J=1 TO 4
240  LET B=J*C
250  LET D=B
260  IF ABS B>=1 THEN LET D= -1/B
270  LET Z=2*D*D-1
280  LET BREG=12
290  REM USE "SERIES GENERATOR"
300  GO SUB 550
310  LET T=D*T
320  IF B > =1 THEN LET T=T+PI/2
330  IF B < =-1 THEN LET T=T-PI/2
340  PRINT TAB 8;"ATN ";B
350  PRINT
360  PRINT T,ATN B          (or PRINT T*180/PI,ATN B*180/PI
370  PRINT                   to obtain the answers in degrees)
380  NEXT J
390  GO TO 160
```

NOTES:

I. When C is entered this program calculates and prints ATN C, ATN (C*2), ATN (C*3) and ATN (C*4). For a specimen of results, try entering these values: 0.2; -1; 10 and -100. The results may be found more interesting if converted to yield degrees by multiplying the answers in line 360 by 180/PI.

II. The constants A(1) to A(12) in lines 40 to 150 are given (apart from a factor of 1/2) in Abramowitz and Stegun Handbook of Mathematical Functions (Dover 1965) page 82. They can be checked by integrating ATN X/X over the interval U=0 to PI, after first multiplying by COS (N*U) for each parameter (i.e. for n=1,2,...,12) and substituting COS U=2*X*X-1. Each result should then be divided by PI.

An alternative subroutine for SIN X:
It is straightforward to produce the full expansion of the Chebyshev polynomials and this can be written in BASIC as follows:

```
550  LET T  =(32*Z*Z*Z*Z*Z-40*Z*Z*Z+10*Z)*A(1)
            +(16*Z*Z*Z*Z-16*Z*Z+2)*A(2)
            +(8*Z*Z*Z-6*Z)*A(3)
            +(4*Z*Z-2)*A(4)
            +2*Z *A(5)
            +A(6)
560  RETURN
```

This subroutine is called instead of the SERIES GENERATOR and can be seen to be of a similar accuracy.

An alternative subroutine for EXP X:
The full expansion for EXP X is:

```
550  LET T  =(128*Z*Z*Z*Z*Z*Z*Z-224*Z*Z*Z*Z*Z+112*Z*Z*Z-14*Z)*A(1)
            +(64*Z*Z*Z*Z*Z*Z-96*Z*Z*Z*Z+36*Z*Z-2)*A(2)
            +(32*Z*Z*Z*Z*Z-40*Z*Z*Z+10*Z)*A(3)
            +(16*Z*Z*Z*Z-16*Z*Z+2)*A(4)
            +(8*Z*Z*Z-6*Z)*A(5)
            +(4*Z*Z-2)*A(6)
            +2*Z*A(7)
            +A(8)
560  RETURN
```

The expansion for LN X and A TN X, given algebraically, will be:

$$
\begin{aligned}
&(2048z^{11}-5632z^{9}+5632z^{7}-2464z^{5}+440z^{3}-22z) * A(1)\\
+\ &(1024z^{10}-2560z^{8}+2240z^{6}-800z^{4}+100z^{2}-2) * A(2)\\
+\ &(512z9-1152z7+864z5-240z3+18z) * A(3)\\
+\ &(256z8-512z6+320z4-64z2+2) * A(4)\\
+\ &(128z7-224z5+112z3-14z) * A(5)\\
+\ &(64z6-96z4+36z2-2) * A(6)\\
+\ &(32z5-40z3+10z) * A(7)\\
+\ &(16z4-16z2+2) * A(8)\\
+\ &(8z3-6z) * A(9)\\
+\ &(4z2-2) * A(10)\\
+\ &(2z) * A(11)\\
+\ &A(12)
\end{aligned}
$$

THE 'DRAW' ALGORITHM

The following BASIC program illustrates the essential parts of the DRAW operation when being used to produce a straight line. The program in its present form only allows for lines where X > Y.

```
 10  REM DRAW 255,175 PROGRAM
 20  REM SET ORIGIN
 30  LET PLOTx=0: LET PLOTy=0
 40  REM SET LIMITS
 50  LET X=255: LET Y=175
 60  REM SET INCREMENT,i
 70  LET i=X/2
 80  REM ENTER LOOP
 90  FOR B=X TO 1 STEP -1
100  LET A=Y+i
110  IF X> A THEN GO TO 160
120  REM UP A PIXEL ON THIS PASS
130  LET A=A-X
140  LET PLOTy=PLOTy+1
150  REM RESET INCREMENT,i
160  LET i=A
170  REM ALWAYS ALONG ONE PIXEL
180  LET PLOTx=PLOTx+1
190  REM NOW MAKE A PLOT
200  PLOT PLOTx,PLOTy
210  NEXT B
```

A complete algorithm is to found in the following program, as a subroutine that will 'DRAW A LINE' from the last position to X,Y.

THE 'CIRCLE' ALGORITHM

The following BASIC program illustrates how the CIRCLE command produces its circles.

Initially the number of arcs required is calculated. Then a set of parameters is prepared in the 'memory area' and the 'calculator stack'.

The arcs are then drawn by repeated calls to the line drawing subroutine that on each call draws a single line from the 'last position' to the position 'X,Y'.

Note: In the ROM program there is a final 'closing' line but this feature has not been included here.

```
 10  REM A CIRCLE PROGRAM
 20  LET X=127: LET Y=87: LET Z=87
 30  REM How many arcs?
 40  LET Arcs=4*INT (INT (ABS (PI*SQR Z)+0.5)/4)+4
 50  REM Set up memory area; M0-M5
 60  LET M0=X+Z
 70  LET M1=0
 80  LET M2=2*Z*SIN (PI/Arcs)
 90  LET M3=1-2*(SIN (PI/Arcs)) ^ 2
100  LET M4=SIN (2*PI/Arcs)
110  LET M5=2*PI
120  REM Set up stack; Sa-Sd
130  LET Sa=X+Z
140  LET Sb=Y-Z*SIN (PI/Arcs)
150  LET Sc=Sa
160  LET Sd-Sb
170  REM Initialise COORDS
180  POKE 23677,Sa: POKE 23678,Sb
190  LET M0=Sd
200  REM 'DRAW THE ARCS'
210  LET M0=M0+M2
220  LET Sc=Sc+M1
230  LET X=Sc-PEEK 23677
240  LET Y=M0-PEEK 23678
```

```
250  GO SUB 510
260  LET Arcs=Arcs-1: IF Arcs=0 THEN STOP
270  LET MM1=M1
280  LET M1=M1*M3-M2*M4
290  LET M2=MM1*M4+M2*M3
300  GO TO 210

500  REM 'DRAW A LINE' from last position to X,Y
510  LET PLOTx=PEEK 23677: LET PLOTy=PEEK 23678
520  LET dx=SGN X: LET dy=SGN Y
530  LET X=ABS X: LET Y=ABS Y
540  IF X> =Y THEN GO TO 580
550  LET L=X: LET B=Y
560  LET ddx=0: LET ddy=dy
570  GO TO 610
580  IF X+Y=0 THEN STOP
590  LET L=Y: LET B=X
600  LET ddx=dx: LET ddy=0
610  LET H=B
620  LET i=INT (B/2)
630  FOR N=B TO 1 STEP -1
640  LET i=i+L
650  IF i < H THEN GO TO 690
660  LET i=i-H
670  LET ix=dx: LET iy=dy
680  GO TO 700
690  LET ix=ddx: LET iy=ddy
700  LET PLOTy=PLOTy+iy
710  IF PLOTy <0 OR PLOTy > 175 THEN STOP
720  LET PLOTx=PLOTx+ix
730  IF PLOTx <0 OR PLOTx > 255 THEN STOP
740  PLOT PLOTx,PLOTy
750  NEXT N
760  RETURN
```

NOTE ON SMALL INTEGERS AND -65536.

1. Small integers n are those for which -65535 is less than or equal to n which is less than or equal to 65535. The form in which they are held is described in 'STACK-BC'. Note that the manual is inaccurate when it says that the third and fourth bytes hold n plus 131072 if n is negative. Since the range of n is then -1 to -65535, the two bytes can only hold n plus 131072 if it is taken mod 65536; i.e. they hold n plus 65536. The manual is fudging the issue. The fact is that this is not a true twos complement form (as the form n plus 131072, in other circumstances, could be). Here the same number can stand for two different numbers according to the sign byte: e.g. 00 01 stands for 1 if the sign byte is 00 and for -65535 if the sign byte is FF; similarly FF FF stands for 65535 if the sign byte is 00 and for -1 if the sign byte is FF.

2. Accepting that negative numbers are given a special 'twos complement' form, the main feature about this method of holding numbers is that they are ready for 'short addition' without any further twos complementing. They are simply fetched and stored direct by the addition subroutine. But for multiplication they need to be fetched by INT-FETCH and stored afterwards by INT-STORE. These subroutines twos complement the number when fetching or storing it. The calls to INT-STORE are from 'multiply' (after 'short multiplication'), from 'truncate' (after forming a 'small integer' between -65535 and 65535 inclusive), from 'negate'/'abs' for the 'integer case' and from 'sgn' to store 1 or -1. The calls to INT-FETCH are from PRINT-FP to fetch the integer part of the number when it is 'small', from 'multiply' twice to fetch two 'small integers', from 'RE-STACK' to fetch a 'small integer' for re-stacking, from 'negate'/'abs' to fetch a 'small integer' for manipulation and from FP-TO-BC to fetch the integer for transfer to BC.

The Number -65536.

3. The number -65536 can fit into the 'small integer' format as 00 FF 00 00 00. It is then the 'limiting number', the one which when twos complemented overflows (cf. 80 hex in a simple one byte or 7 bit system, i.e. -128 decimal, which when twos complemented still gives 80 hex i.e. -128 decimal since the positive number 128 decimal does not fit into the system).

4. Some awareness of this may have inspired the abortive attempt to create 00 FF 00 00 00 in 'truncate'. It is abortive since it does not even survive the INT routine of which 'truncate' is a part. It just leads to the mistake INT (-65536) equals -1.

5. But the main error is that this number has been allowed to arise from 'short addition' of two smaller negative integers and then simply put on the stack as 00 FF 00 00 00. The system cannot cope with this number. The solution proposed in 'addition' is to form the full five byte floating-point form at once; i.e. test for the number first, at about byte 3032, as follows:

```
3032                PUSH    AF                  Save the sign byte in A.
3033                INC     A                   Make any FF in A into 00.
3034                OR      E                   Test all 3 bytes now for zero.
3035                OR      D
3036                JR      NZ,3040,ADD-STORE   Jump if not -65536.
3038                POP     AF                  Clear the stack.
3039                LD      (HL),+80            Enter 80 hex into second byte.
303B                DEC     HL                  Point to the first byte.
303C                LD      (HL),+91            Enter 91 hex into the first byte.
303E                JR      3049,ADD-RSTOR      Jump to set the pointer and exit.
3040    ADD-STORE   POP     AF                  Restore the sign byte in A.
3041                LD      (HL),A              Store it on the stack.
3042                INC     HL                  Point to the next location.
3043                LD      (HL),E              Store the low byte of the result.
3044                INC     HL                  Point to the next location.
3045                LD      (HL),D              Store the high byte of the result.
3046                DEC     HL                  Move the pointer back to
3047                DEC     HL                  address the first byte of the
3048                DEC     HL                  result.
3049    ADD-RSTOR   POP     DE                  Restore STKEND to DE.
304A                RET                         Finished.
```

6. The above amendment (i.e. 15 extra bytes) with the omission of bytes 3223 to 323E inclusive from 'truncate' should solve the problems. It would be nice to be able to test this. The calls of INT-STORE should not lead to 00 FF 00 00 00 being stacked. In 'multiply' the number will lead to overflow if it occurs, since 65536 will set the carry flag; so 'long' multiplication will be used. As noted at 30E5, the 5 bytes starting there could probably be omitted if the above amendments were made. 'Negate' avoids stacking 00 FF 00 00 00 by treating zero separately and returning it unaltered. Truncate deals separately with -65536, as noted above. SGN stores only 1 and -1.

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The Sinclair Spectrum is a complex microcomputer whose normal operation is controlled by the 16K ROM program that is inside every Spectrum.
In this book, Dr. Ian Logan and Dr. Frank O'Hara examine this program and explain exactly what it is that makes the Spectrum operate in the way that it does.
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Overall, the 16K ROM program offers an extremely wide range of BASIC commands and functions. This book makes all the functions and entry points available for use in your own programs or for modification into your own special routines.
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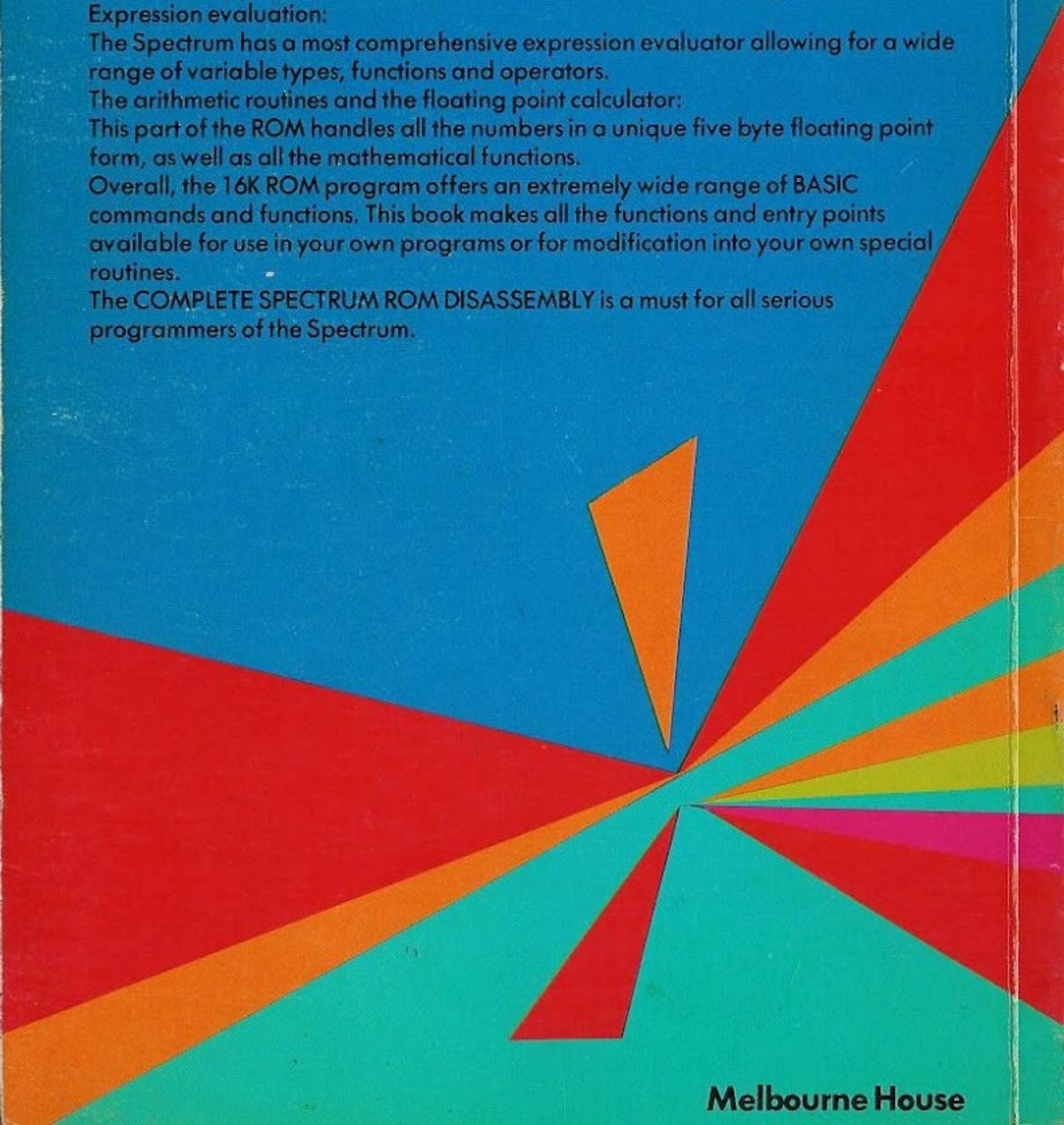

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