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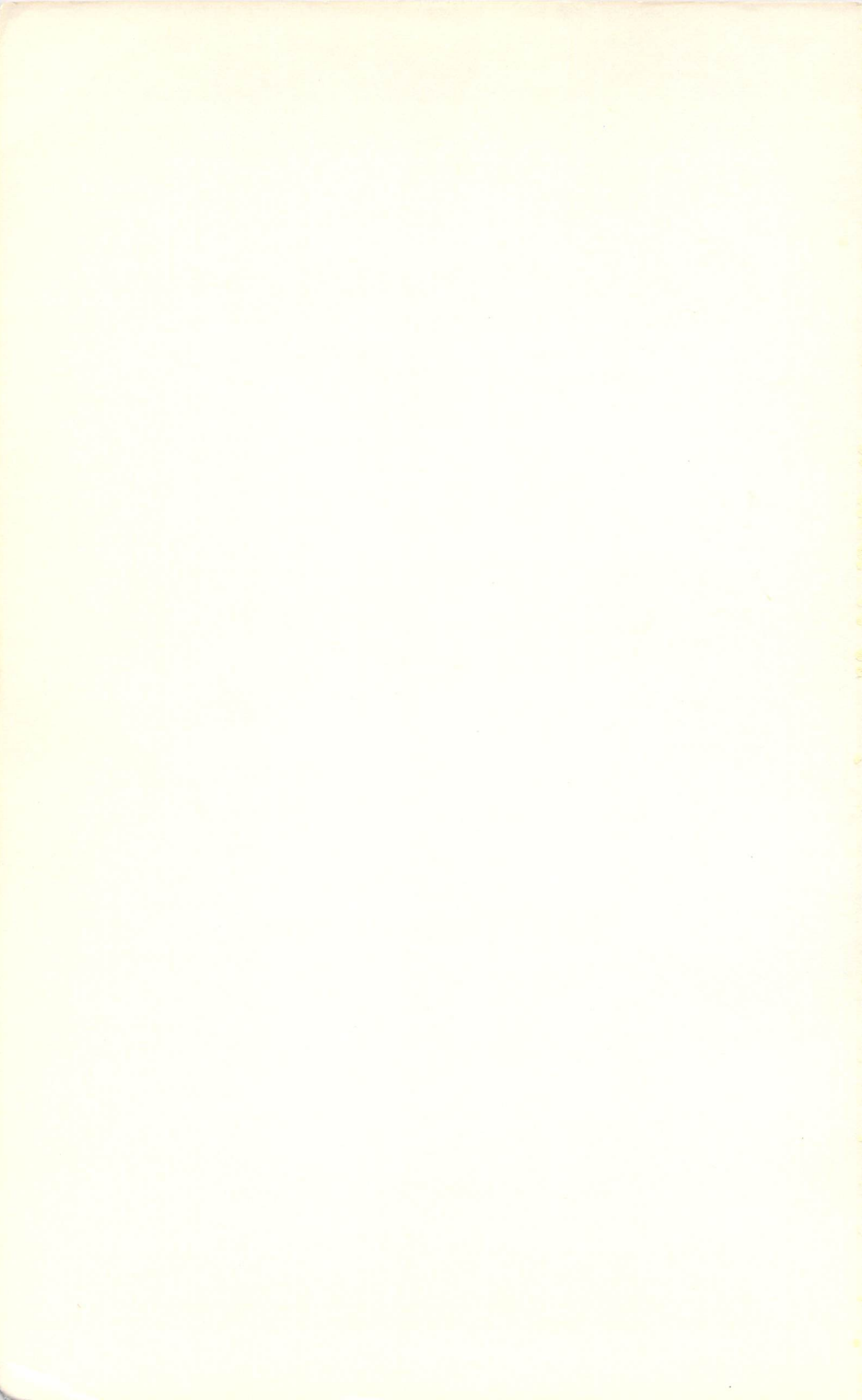
The Commodore 128 Mode: An Inside View

Isaac Malitz
&
Linda Edwards

A programmer's introduction to the Commodore 128's memory organization, operating system and 1571 disk drive.



The Commodore 128 Mode:
An Inside View

by

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and
Linda Edwards

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TABLE OF CONTENTS

Chapter 1 INTRODUCTION 1
Chapter 2 EXPLORING MEMORY 5
Chapter 3 HOW TO ALTER CODES IN MEMORY 11
Chapter 4 PEEKING AND POKING 25
AROUND MEMORY
Chapter 5 HOW CHARACTERS ARE STORED 41
IN MEMORY
Chapter 6 MEMORY SCANNER 51
Chapter 7 THE MAP OF MEMORY 57
Chapter 8 PROGRAMS IN MEMORY 71
Chapter 9 POINTERS 81
Chapter 10 VARIABLES AND AN INTRODUCTION 91
TO BANKS
Chapter 11 DISK STORAGE 107
Chapter 12 DISK STORAGE PART 2 117
Chapter 13 SOUNDS 123
Chapter 14 INTRODUCTION TO NEW C-128 139
GRAPHIC COMMANDS
Chapter 15 MACHINE LANGUAGE 151
Chapter 16 C-128 HARDWARE 163
Chapter 17 CONCLUSION 171

APPENDICES
A. ADVANCED TOPICS 175
B. NOTES ON BASIC 197
C. TECHNICAL NOTES 205
D. BASIC TOKENS AND COLOR CHARTS 211
E. USING THE BUILT-IN MONITOR 215
F. ASCII CHARTS 219

GLOSSARY 223
INDEX 229

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CHAPTER 1: INTRODUCTION

What goes on inside the COMMODORE-128? How does it work? This book will help you to find out.

You will need a COMMODORE-128 computer. And you should know how to write simple programs in BASIC. However, no other special knowledge is needed.

We are going to look at each of the main parts of the COMMODORE-128, and find out how they work together. You will learn about memory, screen, programs and variables, keyboard, disk, graphics, and sound.

You will perform some interesting experiments:

You will find out how to restore a program that has beenaccidentally erased.

You will find out how to "listen" to the inner workings of the COMMODORE-128, using an ordinary radio.

You will write a program which re-writes itself.

You will find out how to make the computer display everthing upside-down.

You will create some amazing effects with sound and with graphics.

When you have finished this book,

You will understand better how a computer works -

- especially the COMMODORE-128.

You will have learned some powerful techniques that you can use when you write your own programs.

You will be prepared to study advanced topics, such as machine language programming or arcade graphics, should you ever want to do this.

The COMMODRE-128 is a mind-boggling machine. Each second, millions of electronic signals pass through it. These signals travel at speeds of nearly 1 billion feet per second. They criss-cross and interact with dazzling complexity. They are organized to perform tasks that sometimes are almost completely beyond the capability of human beings.

How does the COMMODORE-128 work? What goes on in there?

Let's find out ...

Commodore 128 Hints

The following tips will help you to enjoy your exploration of the COMMODORE-128

1. We will suggest lots of experiments in this book. We encourage you to try them, and to even make up your own experiments. You will have fun, and you will learn a lot about your COMMODORE-128. Don't worry, you won't break anything

2. Some of our experiments will involve the computer's memory. To clear memory afterwards, turn the computer off, wait ten seconds, and then turn it back on. Do not use a "warm boot" to clear memory, since a warm boot does not necessarily clear all areas of memory. Whenever you have finished a session with this book, and you want to do something else at the computer, always clear memory, as described above. Otherwise your experiments may leave stray information in memory that could interfere with the processing of other programs.

3. If you have a disk drive or cassette recorder, some of our experiments may alter data on disk or tape. Make up a special diskette or tape, to be used only with this book.

4. Nothing in this book will require you to open your computer. We recommend that you not open your computer, except with guidance from an expert.

CHAPTER 2
EXPLORING MEMORY

The fastest way to start learning about the COMMODORE-128 is to look inside its memory. Whatever is happening inside the COMMODORE-128, the memory usually knows about it.

> When you are running a program, the program and its variables are in the C-128's memory.
>
> The memory knows at all times what line of the program is currently being executed.

The memory knows what is being displayed on the screen.

> When the computer is sending or receiving signals from a disk drive, screen, printer, keyboard, joystick, or anything else attached to the computer, memory usually knows about it.

Let's define what is meant by "memory":

Memory is the part of your computer that holds information that the computer is currently using.
When you are running a program,the program and all of its variables are held in memory. Memory is also used for many other purposes, as we shall see. Memory is divided into a large number of "storage locations". Each location is like a little box that can store a small amount of information. The locations are numbered 0, 1, 2, 3, and so on. Each location can hold one "byte" of information. A byte is about the same as one character of information. A byte is stored as a value ranging from 0-255. If you look in any location in memory,

you will find a value from 0-255.

```
1      2      3      4      5      6      7      8      9      10
........
246  247    248    249    250    251    252    253    254    255
```

A COMMODORE-128 normally comes with "128K" of memory. "128K" means 128 thousand bytes, or 128 thousand storage locations (Actually, there are slightly more than 128 thousand locations. more on this later). Additionally, the C-128 has some special-purpose memory for its internal use, which normally you cannot access. We will find out more about this later. Altogether, a COMMODORE-128 has about 196K of memory of all types.

If you could look into the COMMODORE-128's memory, it would show you almost everything that is happening in the computer. You can look into the memory by using the PEEK command. Let's find out how to do this. We are going to write a program in BASIC called PEEKDEMO. This program will show you how to use the PEEK command to look into the computer's memory.

Here is what PEEKDEMO does:

First it clears the screen.

Then it displays the following message in the upper left-hand corner of the screen:

BAD-CAT !!

Then it displays part of the memory that tracks what is on the screen.

ENTER THIS PROGRAM

```
1 REM PEEKDEMO
2 REM DEMO OF PEEK COMMAND
100 PRINT CHR$(147);
```

```
110 PRINT "BAD-CAT !!"
200 PRINT:PRINT
210 FOR I = 1024 TO 1033
220 P = PEEK(I)
230 PRINT P;
240 NEXT I
```

If you have a disk drive or cassette recorder, save this program under the name PEEKDEMO. We will be writing many programs in this book. We suggest that you save them. In that way you will build up a useful collection of programs for computer-snooping. Save all programs under the name listed in the first line of the program.

Now, run the program. Here is what you will see on your screen:

```
BAD-CAT !!

2  1  4  45  3  1  20  32  33  3
```

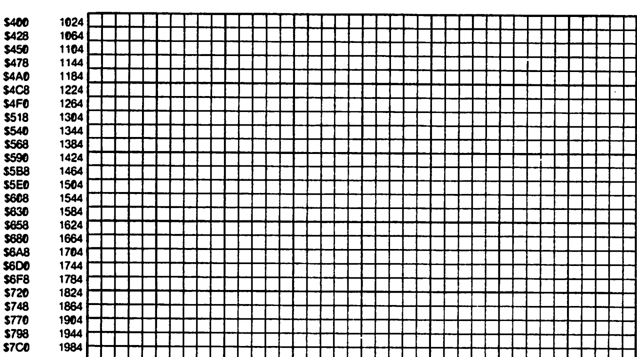
Those codes on the second line are memory's way of describing the upper left-hand corner of the screen. Each of the codes has a meaning. Here is what they mean:

```
2  1  4  45   3  1  20  32  33  33

B  A  D  -    C  A  T        !   !
```

Each of the codes 2, 1, 4, and so on stand for a character that is displayed on the screen. Each code occupies one byte of memory. The value of each code can range from 0 to 255.

These codes are stored in a section of memory whose purpose is to track what characters are on the screen. This section of memory starts at location 1024, and continues for 1000 bytes to location ~~1123.~~ This section of memory is known as "screen memory". Screen memory consists of 1000 bytes of information. This corresponds exactly to the 1000 positions on your screen (25 rows of 40 characters each). This is on the 40 column screen; not the 80 column.



Wherever you see a character on your screen, there is a corresponding location in memory which holds a code which stands for that character. For instance, when the letter 'B' is in the upper left-hand corner, the code 2 is in memory location 1024. As we shall see shortly, if you alter any of the codes for the screen, the appearance of the screen will change.

Let's go back and look at your program PEEKDEMO, and find out how it works.

HOW PEEKDEMO WORKS:

Lines 100 - 110

```
100 PRINT CHR$(147);
110 PRINT "BAD-CAT !!"
```

clear the screen and display "BAD-CAT !!" in the upper left-hand corner. The command in Line 100

```
PRINT CHR$(147);
```

is a programming trick for clearing the screen and positioning the cursor in the upper left-hand corner. This is equivalent to pressing SHIFT-CLR from the keyboard.

The FOR - NEXT loop in lines 200 - 230

```
200 FOR I = 1024 TO 1033
220 P = PEEK(I)
230 PRINT P;
240 NEXT I
```

processes the first 10 bytes starting with byte 1024. Line 220

```
220 P = PEEK(I)
```

finds out the code in one of the bytes of memory. For instance, if I is 1024, then the PEEK command finds out what code is in byte 1024, and it places the value in the variable P.

Line 230

```
230 PRINT P;
```

displays the variable P on the screen.

You can use the PEEK command to look at any part of memory. The positions in memory are numbered from 0 to 65535 (If the C-128 has aapproximately 196K memory locations, how can PEEK get at all these locations? We will explain this in Ch. 7, THE MAP OF MEMORY). To look at any location in memory, simply designate its location with the PEEK command. For instance, to look at location 11235, use

```
PEEK(11235)
```

To help you find your way around memory, a "memory map" and other useful information will be provided later. We also will write a more powerful version of PEEKDEMO that will help you to look through memory. Some parts of memory involve difficult codes and are complex to analyze. But you also will be pleased to find how much of memory you can

understand by the end of this book.

CHAPTER 3
HOW TO ALTER CODES IN MEMORY

In the last chapter, we saw how to use PEEK to look around in memory. We saw that memory is filled with codes. If those codes are altered, amazing things can happen! Let's find out how to alter codes in memory.

To do this, we use the POKE command

RUN THIS PROGRAM:

```
1 REM POKEDEMO1
2 REM DEMO OF POKE COMMAND
100 PRINT CHR$(147);
110 PRINT "BAD-CAT !!"
200 REM LINE 210 CAUSES A 5 SECOND PAUSE
210 FOR X = 1 TO 3500:NEXT X
220 POKE 1024,26
```

Here is what happens when you run POKEDEMO:

The screen is cleared.

In the top left-hand corner you will see

BAD-CAT !!

After about 5 seconds, the first letter on the screen will change to a Z. The screen will then show

ZAD-CAT !!

How was this done ?

Line 220

```
220 POKE 1024, 26
```

tells the computer to store code 26 in memory location 1024. As we saw in the last section, this memory location indicates what character is in the first position on the screen (i.e., the upper left-hand corner). Code 26 stands for "Z". So the character displayed on the screen is a "Z"

Line 210

```
210 FOR X = 1 TO 3500:NEXT X
```

is used to cause a 5 second delay. It is a FOR - NEXT loop which does nothing but count from 1 to 3500. This takes about 5 seconds.

Let's try some more pokes. To make this easy, we will revise POKEDEMO1 so that you can enter variable poke information.

ENTER THIS PROGRAM:

```
1 REM POKEDEMO2
100 SP$ = "          "
110 PRINT CHR$(147);
120 PRINT "BAD-CAT !!"
200 PRINT CHR$(19);TAB(200);
210 PRINT SP$:PRINT SP$
220 PRINT CHR$(19);TAB(200);
230 INPUT "LOCATION";L
240 INPUT "CODE";C
250 POKE L,C:GOTO 200
```

Run the program.

The screen will clear. At the top of the screen you will see

BAD-CAT !!

In the middle of the screen you will see

LOCATION?

Type 1024 and press RETURN. This tells the computer that we want to POKE something into memory location 1024.

Now a second question will appear:

CODE?

Type 18 and press RETURN. This tells the computer that you want to POKE the code 18 into the memory location.

Code 18 stands for "R", and your screen display will change to

RAD-CAT !!

The computer will now ask you for another LOCATION IN MEMORY and VALUE TO POKE. Here are some values to try:

LOCATION IN MEMORY	CODE TO POKE	EFFECT
1026	20	RAT-CAT !!
1025	0	R@T-CAT !!
1029	83	CAT gets a heart
1028	131	Reverse video

A complete chart of screen codes and symbols produced is at the end of the chapter.

So far, all of our screen displays have been in black and white. The COMMODORE-64 is also able to display characters in color -- 16 colors in all. Each position on the screen can be assigned any one of these 16 colors. How can this be done?

Well, there is a section of memory, called "color memory", which tracks the color of each of the 1000 positions on the screen. Here's how it works:

Color memory starts at location 55296, and continues for 1000 bytes to location 56295. Each of the locations in color memory corresponds to one of the positions on the screen.

When you POKE a value of 0 - 15 into a location in screen memory, this will assign a color to a certain position on the screen. The list of colors is as follows:

0	BLACK	8	ORANGE
1	WHITE	9	BROWN
2	RED	10	LT RED
3	CYAN	11	GRAY 1
4	PURPLE	12	GRAY 2
5	GREEN	13	LT GREEN
6	BLUE	14	LT BLUE
7	YELLOW	15	GRAY 3

Let's POKE some values into color memory and see what happens. To do this, we can use POKEDEMO again.

Stop POKEDEMO by pressing STOP-RESTORE.

Now, RUN the program again. Once again, at the top of your screen, you will see

BAD-CAT !!

Now, try these POKEs:

LOCATION IN MEMORY	CODE TO POKE	EFFECT
55296	8	B turns orange
56297	5	A turns green
55298	2	D turns red

Locations 55296, 55297, and 55298 correspond to the first three positions on the screen. The color codes which you POKEd into these locations assigned colors to the first three positions on the screen.

By POKEing the right values into screen memory and color memory, you can put characters anywhere on the screen, and make them any color you want. There is once "catch" however:

If you POKE a character into a new position on the screen, you will not actually see the character until you also assign it a color in color memory.

In other words, if you want to display a character on the screen in a new position, you must both select a character and a color for that position. Let's try an example to illustrate this rule.

Use the program to POKE these two values:

LOCATION IN MEMORY	CODE TO POKE	EFFECT
2023	83	No visible effect
56295	8	Orange heart at bottom right-hand corner

Here is an explanation of what happened:

When you POKEd 83 into location 2023, this placed a heart at the bottom right-hand corner of the screen. 83 is the code for a heart. 2023 corresponds to the bottom right-hand corner of the screen.

Unfortunately, the heart was not visible, because we did not yet assign a color to that position on the screen.

When you POKEd 8 into location 56295, this assigned the color orange to the bottom right-hand corner of the screen. This "colored" the heart orange, and made it visible.

If you would like a more detailed explanation of why the heart was not visible until you did a POKE into color memory, see the TECHNICAL NOTES at the end of the book.

Experiment with some other values. LOCATION can be any number from 1024 to 2023, or 55296 to 56295. CODE can be any value from 0 to 255. Here are a few more sample values to try:

LOCATION IN MEMORY	CODE TO POKE	EFFECT
2023	90	Diamond in lower right-hand corner
1983	90	No visible effect
56235	1	White diamond in lower left-hand corner
1983	129	Reverse video diamond lower left-hand corner

When you want to stop the program, press RUN STOP - RESTORE.

Let's summarize what we have found out about memory and the screen.

The screen consists of 1000 positions -- 25 rows, with 40 positions in each row.

There is a portion of memory (locations 1024 - 1123) which tracks what character is in each position on the screen. There is a one-to-one correspondence between the positions on the screen, and the bytes in this portion of memory. Each memory location may have any value from 0 to 255. At the end of this chapter is a chart which shows what character each possible byte value stands for.

There is another portion of memory (locations 55296 - 56295) which tracks the color of each position on the screen. There is a one-to-one correspondence between the positions on the screen, and the bytes in this portion of memory. Each memory location may have a value of 0 - 15, for a total of 16 possible colors. At the end of this chapter is a chart which shows what each possible byte value stands for.

In order for a character to appear on the screen, two codes are needed: a character code in screen memory, and a color code in color memory. If you just POKE a code into screen memory, this will not put anything up on the screen; you must also POKE a character into color memory.

HOW POKEDEMO WORKS:

Line 100

```
100 SP$ = "               "
```

sets up a variable which consists of 15 spaces, and which will be used to erase information from the screen.

Lines 110 - 120

```
110 PRINT CHR$(147);
120 PRINT "BAD-CAT !!"
```

do the same job as in the previous programs.

Lines 200 - 220

```
200 PRINT CHR$(19);TAB(200);
210 PRINT SP$:PRINT SP$
220 PRINT CHR$(19);TAB(200);
```

clear lines 6 and 7 of the screen, and then position the cursor at the beginning of line 5.

PRINT CHR$(19); positions the cursor at the top of the screen.

TAB(200); moves the cursor down 5 lines (which is the same as 200 spaces)

PRINT SP$ puts 15 blank spaces on the screen

Lines 230 - 240 allow you to INPUT your POKE information:

```
230 INPUT "LOCATION";L
240 INPUT "CODE";C
```

Line 250

```
250 POKE L,C:GOTO 200
```

does the POKE-ing, and then transfers back to line 200.

There are a great number of possible combinations of characters colors. The following program will show you all of the possibilities.

RUN THIS PROGRAM:

```
1 REM SHOWALL
100 PRINT CHR$(147);
200 FOR I = 0 TO 255
210 POKE 1024+I,I
220 NEXT I
300 FOR  C = 0 TO 15
310 FOR I = 55296 TO 55551
```

```
320 POKE I,C
330 NEXT I
340 NEXT C
```

HOW SHOWALL WORKS:

This program has two parts.

The **first part**

```
100 PRINT CHR$(147);
200 FOR I = 0 TO 255
210 POKE 1024+I,I
220 NEXT I
```

clears the screen, and then places all 256 possible characters on the screen, starting in the upper left-hand corner. (The characters will not be visible to you, until the second half of the program assigns colors to the characters.)

The **second part**

```
300 FOR  C = 0 TO 15
310 FOR I = 55296 TO 55551
320 POKE I,C
330 NEXT I
340 NEXT C
```

colors the characters in each of the 16 possible colors (0-15). C stands for the color. The FOR - NEXT loop

```
300 FOR C = 0 TO 15
.
.
.
340 NEXT C
```

takes C through the range of possible values, 0 - 15. For each of these values, the 256 characters are "colored" with that value:

```
310 FOR I = 55296 TO 55551
```

```
320 POKE I, C
330 NEXT I
```

Actually, there is another complete character set, which is available in the computer, which is not demonstrated in this program. It is disscussed in the Commodore - 128 Programmer's Reference Guide.

This next program creates a banner from a message that you enter.

RUN THIS PROGRAM:

```
1 REM HOTBAN
100 B=1024
110 INPUT "MESSAGE";M$
120 M$=M$ + " "
130 L=LEN(M$)
200 PRINT CHR$(147);M$
210 FOR I=0 TO 999
220 P=PEEK(B+M)
230 POKE B+I,P
240 M=M+1:IF M=L THEN M=0
250 NEXT I
300 FOR I=55296 TO 56295
310 R= INT(16*RND(1))
320 POKE I,R
330 NEXT I
400 GOTO 300
```

When you run this program, you will be asked to enter a message. Enter any message, up to 255 characters in length. Then press RETURN. The program will cover the screen with your message, and make it sparkle with many different colors.

HOW HOTBAN WORKS:

This program has three parts.

The first part

```
100 B=1024
110 INPUT "MESSAGE";M$
120 M$=M$ + " "
```

```
130 L=LEN(M$)
```

takes care of preliminaries. Line 100 sets variable B to 1024, which is the beginning of screen memory. Line 110 allows you to INPUT a message, into variable M$. Line 120 "pads" M$ with a blank space, which will help the message to display more attractively. Line 130 stores the length of the message into variable M$.

The **second part** of the program

```
200 PRINT CHR$(147);
210 FOR I=0 TO 999
220 P=PEEK(B+M)
230 POKE B+I,P
240 M=M+1:IF M=L THEN M=0
250 NEXT I
```

fill the screen with your message. To begin with, line 200

```
200 PRINT CHR$(147);M$
```

clears the screen, and displays the message once in the top left-hand corner. Then the FOR-NEXT loop

```
210 FOR I=0 TO 999
.
.
.
250 NEXT I
```

copies the message onto the rest of the screen. The variable I counts from 0 to 999, which corresponds to the 1000 positions on the screen. For each value of I, a character is "extracted" from your message, and then it is POKEd into one of the locations in screen memory. The "extraction" is done in line 220

```
220 P=PEEK(B+M)
```

This PEEKs at one of the characters of the message in the top of the screen. M is always less than the length of the message. B is the beginning of screen memory. So

```
P=PEEK(B+M)
```

will always extract one of the characters in the message at the top of the screen. The character which is extracted will depend on the value of M. This starts at 0, increases to the length of the message, drops back to 0 and starts over again. The value of M is controlled by line 230.

The POKEing is done by line 240

```
240 POKE B+I,P
```

This will POKE the value P into one of the positions in screen memory. The position is determined by I, which starts at 0 and increases to 999.

So in summary, the second part of the program uses the variables M and I to copy the message over the entire screen.

The **third part** of the program

```
300 FOR I=55296 TO 56295
310 R= INT(16*RND(1))
320 POKE I,R
330 NEXT I
400 GOTO 300
```

makes the screen sparkle with color.

The FOR - NEXT loop in this section traces through the 1000 positions in color memory. At each position, a random number from 0 - 15 is generated.

```
310 R= INT(16*RND(1))
```

This stands for a color code of 0 - 15. The color code is then POKEd into a location in color memory:

```
320 POKE I,R
```

So over and over again, color memory is POKEd with random color codes. This makes your screen-ful of messages sparkle with many colors.

Line 400

```
400 GOTO 300
```

causes the random coloring process to repeat forever. The program will not stop by itself. You must stop it by pressing the STOP key, or by turning off the computer.

Chapter 4
PEEKING AND POKING AROUND MEMORY

We have now explored two regions of memory: screen memory and color memory. There are many other regions of memory where it is interesting to PEEK and POKE. In this section, we will explore a few of them. Not only will this be fun, but also you will get a sense for the variety of ways in which memory is used.

There are several locations in memory which keep track of what keys have been pressed on the keyboard. The following program will show you how two of these memory locations track the keyboard.

SPECIAL KEYS

There are several special keys are not used very often, and you may not be familiar with everything they can do. Here is a quick summary. For additional information on special keys and other features of the keyboard, see the COMMODORE 128 SYSTEM GUIDE which came with your computer.

Commodore wanted to provide you with a keyboard having a great number of features. However the number of features would have required several separate keyboards. Commodore solved this problem by providing you actually several keyboards in one unit. The purpose of some of the special keys is to transform all or part of your regular keyboard into a special keyboard. The following discussion will guide you through the various capabilities of your keyboard. Used normally, the main part of the keyboard produces capital letters. The top row produces numbers.

If you press a SHIFT key (either the left-hand SHIFT key, or the right-hand SHIFT key, or the SHIFT LOCK key), this transforms the main part of the keyboard into a "graphics" keyboard. Each key will produce the graphic character shown on the right hand side of the front part of the key.

EXPERIMENT: Press a SHIFT key, and while you are holding it down, press the letter Z. A diamond will appear on the screen.

The SHIFT keys transform the top row of the keyboard into a "special symbols" keyboard.

EXPERIMENT: Press a SHIFT key, and while you are holding it down, press the number 4. A dollar sign ($) will appear on the screen.

The Commodore key (the key in the lower left-hand corner of the keyboard) transforms the keyboard into a yet another "graphics" keyboard. When the Commodore key is held down each key will produce the graphic character shown on the left hand side of the front part of the key.

EXPERIMENT: Press the Commodore key, and while you are holding it, press the letter Z. A "right-angle" symbol will appear on the screen.

The Commodore key transforms the top row of the keyboard into a set of "color switches." The color assigned to each key is marked on the front of the key.

EXPERIMENT: Press the Commodore key, and while you are holding it down, press the number 6. Let go of the Commodore key, and press a few keys. All symbols will be colored light green.

The CTRL key transforms the top row of the keyboard into a different set of color switches.

EXPERIMENT: Press the CTRL key, and while you are holding it down, press the number 6. Let go of the CTRL key, and press a few keys. All symbols will be colored dark green.

If you press and hold down a SHIFT key, and then press the Commodore key, this transforms the main part of the keyboard into a "lower case" keyboard.

EXPERIMENT: Press and hold down a SHIFT key, and then press the Commodore key. Let go of both keys, and type a few letters. Everything will appear in lower case. Now, hold down a SHIFT key and type a few letters. Everything will appear in upper case.

That completes a quick survey of the various keyboards that are packaged into your COMMODORE-128. Now, here are some other special keys and key combinations:

If you press RUN/STOP when a program is running, it will normally stop the program. (There are some situations where you must press RUN/STOP and RESTORE to stop a program. Also, it is possible to write programs which cannot be stopped, except by turning off the computer.) The combination of RUN/STOP and RESTORE will turn off most special keyboard features, and "restore" the computer to normal.

CLR/HOME will move the cursor to the upper left-hand corner of the screen. If you press CLR/HOME while holding down a SHIFT key, it will also clear the screen. (However, if there is a program in memory, it will not clear the program or its variables.)

The two CRSR keys allow you to "navigate" the cursor around the screen, right-left and up-down.

INS/DLT is used for inserts and deletions when you are entering data.

CTRL-9 will cause everything to appear in reverse video.

The function keys F1 - F8 (on the right side of your keyboard) do not have any pre-defined purpose. These are "wild card" keys which a programmer may define for special use in a program. For example, in a game, F1 might mean "Fire missile", and F3 might mean "Start new game". In a business program, F1 might mean "Cancel last entry" and F3 might mean "Compute total".

RUN THIS PROGRAM

```
1 REM KBDSTAT
100 PRINT PEEK(213),PEEK(211)
110 GOTO 100
```

You will see the following numbers flash on the screen:

```
88    0
88    0
88    0
```

These are the values currently in bytes 213 and 211 respectively. These two locations track the status of all keys on the keyboard (with the exception of RESTORE, which we will discuss later.) When the values of these locations are 88 and 0, this means that no keys are currently pressed.

Now press Z and hold it down. You will see

```
12    0
12    0
12    0
```

This shows that byte 213 is now 12. And this means that Z is depressed.

Now, release the Z key. The display will change back to

```
88    0
88    0
88    0
```

This means that once again, no keys are currently pressed.

Now, press X and hold it down. You will see

```
23    0
23    0
23    0
```

This means that X is depressed. When you release the X key, the display will change back to

```
88    0
88    0
88    0
```

Experiment with some other keys. You will find that most of them affect only Byte 197. For instance:

```
 KEY              BYTE 213         BYTE 211
---------        --------         --------
R                   17                0
S                   13                0
@                   48                0
SPACE BAR           60                0
```

In fact, there are only three keys that affect Byte 653. These are SHIFT, CTRL, and the Commodore key. Let's see what these keys do.

Press and hold down a SHIFT key. You will see

```
88    1
88    1
88    1
```

Release the SHIFT key. You will see

```
88    0
88    0
88    0
```

Press and hold down the Commodore key. You will see

```
88    2
88    2
88    2
```

Release the Commodore key. Now press and hold down CTRL. You will see

```
88    4
88    4
88    4
```

Why are the SHIFT, CTRL, and Commodore keys tracked in a different location than other keys? The answer is that those three keys are meant to be used *in combination with* other keys. For example, you never use a SHIFT key by itself. When you use the SHIFT key, it is always used along with another key. For instance, if you want to produce a '$', you press SHIFT and 4 together. The computer must keep track of the fact that you have pressed both SHIFT and 4. So it tracks the two events in separate memory locations.

Let's summarize what we have found out so far about memory and the keyboard.

There are certain locations in memory which track what keys have been pressed on the keyboard.

Byte 213 tracks the status of all keys on the keyboard, with the exception of SHIFT, CTRL, the Commodore key, and RESTORE. When a key is depressed, a code assigned to that key appears in byte 213. These codes are called "scan codes". A complete table of scan codes is at the end of the book.

Byte 211 tracks the status of SHIFT, CTRL, and the Commodore key. The scan codes for these keys are as follows:

KEY	VALUE
SHIFT	1
Commodore key	2
CTRL	4

Occasionally it is necessary to press SHIFT and CTRL simultaneously, or SHIFT and the Commodore key, or CTRL and the Commodore key. When this happens, how does memory indicate it?

Let's try an experiment. Hold down SHIFT and the Commodore key at the same time. You will see:

```
88    3
88    3
88    3
```

The number 3 is the sum of the values for SHIFT and the Commodore key. The computer added the two numbers together!

Try pressing SHIFT and CTRL together. You will see

```
88    5
88    5
88    5
```

which is the sum of the values for SHIFT and CTRL.

Press the Commodore key and CTRL together. You will see

```
88    6
88    6
88    6
```

which is the sum of the values for the Commodore key and CTRL.

What do you think will happen if SHIFT, CTRL, and the Commodore key are all pressed at the same time? Try it!

```
88    7
88    7
88    7
```

The computer adds together the values of all three keys.

The values of the three keys have been cleverly planned so that once you know the value in location 211, you can determine exactly which of the three keys have been pressed.

VALUE IN LOCATION 211	KEYS PRESSED		
	SHIFT	Commodore key	CTRL
0	No	No	No
1	Yes	No	No
2	No	Yes	No
3	Yes	Yes	No
4	No	No	Yes
5	Yes	No	Yes
6	No	Yes	Yes
7	Yes	Yes	Yes

This reveals an interesting fact: With just one byte, it is possible to track several separate pieces of information. In this case, a single byte can track the status of three different keys. We shall have more to say about this later.

Locations 54272 - 54296 are responsible for the sound and music capabilities of your COMMODORE-128. Whenever your computer is producing sounds, this is reflected in the values in this memory area.

When you POKE values into this memory area, the computer will produce sounds. To get an idea of the variety of sounds, let's POKE some random numbers into this area and listen to what happens.

RUN THIS PROGRAM:

```
1 REM ZOUNDS1
100 FOR I=54272 TO 54296
110 R = INT(256 * RND(1))
120 POKE I,R
130 NEXT I
140 GOTO 100
```

You will hear all sorts of strange sounds coming out of your computer. ZOUNDS1 is POKEing random numbers into each of the locations 54272 - 54296, over and over again. The random numbers are generated in Line 110

```
110 R = INT(256 * RND(1))
```

This command line generates a random number R between 0 and 255. Then R is POKEd into memory in Line 120

```
120 POKE I,R
```

I varies through the range 54272 - 54296.

When you run ZOUNDS1, you do not hear a solid wall of sound. Instead, you will hear many individual sounds, and many moments of silence imbetween. The reason for this is that not all combinations of numbers produce audible sounds. What can we do to produce more sounds, and fewer moments of silence? There are several possible strategies:

First, we might "tinker" with the program -- we could experiment with various small changes, until the program "gets better".

Second, we might put a "freeze" feature in the program, so that every time the program produces an interesting sound, we can find out what POKEs were used. This information could help us to design niftier sound programs.

Third, we could try to understand in detail how the the computer makes sounds. We could find out what each memory location does to affect the overall sound.

We will use all three strategies. In this chapter, we will use the first two strategies, and then in a later chapter we will get into the third strategy.

First, let's just "tinker" with the program a little. One obvious strategy to try is to modify the random number generator to produce numbers in a more limited range. Or we might limit the range of the FOR - NEXT loop. Here is one experiment which gives better results:

```
1 REM ZOUNDS2
10 POKE 54296,15
100 FOR I=54272 TO 54278
110 R = INT(100 * RND(1))
120 POKE I,R
130 NEXT I
140 GOTO 100
```

This is almost the same program as ZOUNDS1. The random numbers have been limited to the range 0 - 99. The POKE locations have been limited to 54272 - 54278. Also, location 54296 has been permanently set to 15. Location 54296 is the "volume control" for the Synthesizer, and 15 is its maximum volume.

Now let's add a "freeze" feature to the program, so that if it produces a sound we like, we can find out how it was done.

```
1 REM ZOUNDS3
10 POKE 54296,15
100 FOR I=54272 TO 54278
```

```
110 R = INT(100 * RND(1))
120 POKE I,R
125 PRINT R;
130 NEXT I
135 INPUT X$
140 GOTO 100
```

This is the same as ZOUNDS2, except that two lines have been added.
Line 125

```
125 PRINT R;
```

prints the random values that are being POKEd into memory.

Line 135

```
135 INPUT X$
```

"freezes" the program each time the FOR - NEXT loop has been completed. This gives you a chance to decide if you liked the latest sound the program produced, and if you did, to jot down the POKEs that produced the sound.

In Chapter 13, we will explore the sound capabilities of the COMMODORE-64 in more depth. Even after we have done this, though, you will find a program like ZOUNDS3 useful. The synthesizer is very complex in its capabilities and a program like ZOUNDS3 helps you to explore those capabilities in ways that you might not have thought of on your own.

Your computer is equipped with a clock that helps to schedule and organize its activities. The current time from this timer is tracked in bytes 160 - 162. Here is a program that will enable you to watch the clock run.

RUN THIS PROGRAM:

```
1 REM CLOCK
100 A=PEEK(160)
110 B=PEEK(161)
120 C=PEEK(162)
130 D= 65536*A + 256*B + C
140 PRINT A;B;C
150 GOTO 110
```

On your screen you will see a display something like this:

```
0        1        245
0        1        251
0        2          1
0        2          6
0        2         12
```

Each line is a readout of the current time in the clock. This time is kept in three counters, represent by the three columns of your display. When a counter gets past 255, it rolls back to 0 and the next counter to the left is increased by 1. The clock runs at a speed of approx. 60 "ticks" per second. One 60th of a second is called a "jiffy" in computer jargon.

When the computer is turned on the clock is set to 0 -- the value is 0 in locations 160, 161, and 162. So if you read the clock, you can tell how long the computer has been on. The total elapsed time in jiffies is computed as:

65536*PEEK(160) + 256*PEEK(161) + PEEK(162)

Using the last line from our illustration, the total elapsed time would be

```
 65536 * 0     +    256 * 2        +  12

=        0     +    512            +  12

=      524 jiffies
```

Since 1 second = 60 jiffies, this is equal to a little less than 9 seconds.

When you press the letter "Z" on the keyboard, the computer draws a "Z" on the screen. In order to do this, the computer has to know how to draw a "Z". The letter "Z" has a certain shape, and the computer must know that shape. How does the computer know the shape of the letter "Z"?

The answer is that there is a table of values, starting at location 53248, which describes the shapes of the letters of the alphabet, and all other symbols used by the computer. This table is sometimes known as a "shape table". Whenever

the computer wants to draw a symbol on the screen, it consults the shape table to find out the shape of the character. We are going to find out how the shape table works.

From the point of view of the computer, any symbol is imagined as an 8 by 8 grid of dots, where each dot may be "on" or "off". Here is how a "Z" looks to the computer.

```
.*******
.....**.
....**..
...**...
..**....
.**.....
.*******
.......
```

8 by 8 grid of dots, like the one above. That's what a "Z" is, to the computer. (If you examine a "Z" on your screen, you may be able to see the individual dots that make up the character. The pattern of dots is exactly like the above diagram.)

The shape table describes for each character exactly which dots in the grid are "on", and which ones are off. It takes 8 bytes in the shape table to describe the entire grid. One byte is required to describe each row in the grid. In the above example, the 8 bytes are as follows:

```
.*******      127
.....**.        6
....**..       12
...**...       24
..**....       48
.**.....       96
.*******      127
........        0
```

In the next chapter, we will find out how each row is translated into a single one-byte number.

If the information in the shape table could be changed, you could define new symbols that could be produced from the keyboard. For instance, you could modify the shape table so that when the keys

A B C

are pressed on the keyboard, the following three symbols would appear on the screen:

α β χ

(Greek alphabet)

or

栗谷集

(Korean)

The bad news is that the shape table is "protected" from alteration -- if you attempt any POKEs into the region where the Shape Table is located, the values in the table will remain unchanged. (We will find out more about this later.)

The good news is that you can set up your own shape table in a different part of memory, and then tell the computer to use your table instead of the standard Shape Table. You can use your own shape tables to define your own symbols. Let's find out how to do this.

The following program will set up a shape table which generates symbols known as "bar codes". You have probably seen bar codes in grocery stores -- they are a common method for identifying and pricing merchandise.

Our program will set up the new shape table beginning at Location 12288. Here is a partial list of the shapes which will be produced by the new shape table.

```
KEY PRESSED ON THE      SHAPE WHICH APPEARS
    KEYBOARD                ON SCREEN
-----------------       -----------------
        A                        |
        B                      |
        C                      | |
        D                    |
        E                    |   |
        F                    | |
        G                    | | |
        H                  |
        I                  |     |
        J                  |   |
        K                  |   | |
        L                  | |
        M                  | |   |
        N                  | | |
        O                  | | | |
```

RUN THIS PROGRAM:

```
1 REM BARCODES
100 PRINT CHR$(147);"FONE HOME"
200 FOR C=0 TO 63
210 FOR D=0 TO 7
220 POKE 12288 + 8*C + D, C
230 NEXT D
240 NEXT C
300 POKE 2604,28
```

This program will display the message "FONE HOME" on the screen, then there will be a pause of about 15 seconds, while the computer is setting up the new shape table. Then the message will be transformed into bar codes:

The exact appearance of the bar codes will depend on the kind of screen you have. Some screens will blur the bars together slightly.)

Your keyboard has been converted into a "bar code" keyboard. When you press keys, instead of the usual symbols appearing on the screen, you will see bar codes instead. Each key produces a different bar code.

HOW BARCODES WORKS:

For the time being, we will just outline the main features of the program. The details will be clarified in the next chapter.

Line 100

```
100 PRINT CHR$(147);"FONE HOME"
```

clears the screen, and displays the message "FONE HOME" at the top of the screen.

Lines 200 - 240

```
200 FOR C=0 TO 63
210 FOR D=0 TO 7
220 POKE 12288 + 8*C + D, C
230 NEXT D
240 NEXT C
```

create the new shape table, starting at location 12288. The table consists of 64 groups of 8 bytes each. Each group of 8 bytes defines one character, as we shall see in the next chapter. The values of the bytes are as follows:

The first 8 bytes (12288 - 12295) are all 0
The next 8 bytes (12296 - 12303) are all 1
The next 8 bytes (12303 - 12311) are all 2

and so on. Each group of 8 bytes has a value of 1 more than the preceding group. Altogether this defines 64 characters.

The variable C counts through the 64 groups of 8 bytes each. Within each group, the variable D counts through the 8 bytes.

Line 300

```
300 POKE 2604,28
```

tells the computer to use the shape table beginning at location 12288. Depending on the value which is POKEd into location 2604, it is possible to have shape tables at locations other than 12288.

When you would like to get your keyboard back to normal, press RUN/STOP - RESTORE.

CHAPTER 5
HOW CHARACTERS ARE STORED IN MEMORY

In the last chapter, we found out that the shape of every symbol is described in a shape table. Each symbol is imagined as an 8 by 8 grid of dots. Each of the 8 rows in the grid is represented by one byte in the shape table. For instance:

```
.*******        126
.....**.          6
....**..         12
...**...         24
..**....         48
.**.....         96
.*******        126
........          0
```

Now let's find out the precise relationship between the numbers in the Shape Table, and the pattern of dots in each row of the grid. (If you are not interested in technical details, it's okay to skim through this discussion.) If you could look at a single byte of memory under a microscope, you would discover that it consists of eight tiny storage compartments. Each compartment holds one "bit" of information. The value of a bit can be either 0 or 1 ("off" or "on"). For instance, here is how a byte value of 48 looks in memory.

0	0	1	1	0	0	0	0

When you do a PEEK into memory, the computer calculates a value for the entire byte, based on the value of the individual bits. The formula is as follows: Let's call the eight positions a - h, starting from the right, i.e.

```
0   0   1   1   0   0   0   0

h   g   f   e   d   c   b   a
```

Each position is assigned a value:

```
h    128
g     64
f     32
e     16
d      8
c      4
b      2
a      1
```

To calculate the value for the entire byte, add together the values of the bits that are "on".

Let's try a few examples:

```
0   0   1   1   0   0   0   0

h   g   f   e   d   c   b   a
```

The bits which are on are: f, e

The value of f is 32
The value of e is <u>16</u>

The value for the entire byte is 48

```
0   0   0   0   1   1   0   0

h   g   f   e   d   c   b   a
```

The bits which are on are: d, c

The value of d is 8
The value of c is 4

The value for the entire byte is 12

```
0   1   1   0   1   1   0   1

h   g   f   e   d   c   b   a
```

The bits which are on are: g, f, d, c, a

The value of g is 64
The value of f is 32
The value of d is 8
The value of c is 4
The value of a is 1

The value for the entire byte is 109

Now we can summarize how the 8 bytes in the shape table describe the shape of a character.

Each character consists of 8 rows of 8 dots each.

For each row, there is a corresponding byte in the shape table. The pattern of bits in that byte describe the points in that row. So for instance,

CHARACTER	BYTE IN SHAPE TABLE	BIT PATTERN IN BYTE
.*******	126	01111111
.....**.	6	00000110
....**..	12	00001100
...**...	24	00011000
..**....	48	00110000
.**.....	96	01100000
.*******	126	01111111
....	0	00000000

In conclusion, the pattern of bits in the shape table matches

In conclusion, the pattern of bits in the shape table matches the pattern of points in the character.

Here is some jargon about bits which it is useful to be familiar with.

Bit h -- the first one from the left -- is known as the "high order bit", since its value is 128.

Bit a -- the first one from the right -- is known as the "low order bit", since its value is 1.

The eight bits are sometimes referred to as the "bit 0", "bit 1", "bit 2", and so on reading from the right. I.e., "bit 0" is the low order bit, and "bit 7" is the high-order bit. Warning, occasionally this terminology is used in reverse order!

Altogether, there are 256 different possible combinations of bits in a single byte, the value for these various combinations ranges from 0 to 255. A chart of all possible combinations is at the end of this chapter.

By using bits, it is possible to represent any number. This is what is known as "Base Two" or "Binary" notation. It is known as Base Two, because in any number, each digit may have only two values. Our ordinary human notation for numbers is called Base 10, since each digit may have any of ten different values. Here are some examples of numbers in Base Two:

BASE TEN	BASE TWO
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110

64	1000000
99	1100011
100	1100100
101	1100101
102	1100110
128	10000000
256	100000000
512	1000000000
1024	10000000000

Computers frequently express numbers in binary notation. Engineers have discovered that they can design computers that are faster and less expensive, when binary notation is used extensively. The main reason for this is that the most fundamental events in a computer's "life" are binary, switches being open or closed, a flow of current being on or off, a bit of data being present or not present in a certain location.

As we proceed through this book, we shall frequently encounter binary notation. Also, there are certain specific binary numbers which are "favorites" of the computer, and which we shall encounter over and over again:

BASE TEN	BASE TWO
16	10000
32	100000
64	1000000
128	10000000
256	100000000
512	1000000000
1024	10000000000
4096	1000000000000
32768	1000000000000000
65536	10000000000000000

Human beings generally dislike binary notation. All those 0's and 1's are hard on the eyes, and its very difficult to read large numbers. Here we ave a fundamental difference between computers and human beings: Computers generally prefer Base Two, and human beings generally prefer Base Ten.

Now let's have some fun with shape tables. Some of the following discussion will be somewhat technical -- in order to play with shape tables, we must get involved with binary notation. If you are not interested in technical details, its okay

following discussion will be somewhat technical -- in order to play with shape tables, we must get involved with binary notation. If you are not interested in technical details, its okay to skim through the next two examples.

First, we will modify the shape table from the last chapter, so that when you press the letter "@" on your keyboard, a lightning bolt appears on the screen. The program is the same as BARCODES, except that lines 400 - 500 have been added at the end.

RUN THIS PROGRAM:

```
1 REM LIGHTNING
100 PRINT CHR$(147);"FONE HOME"
200 FOR C=0 TO 63
210 FOR D=0 TO 7
220 POKE 12288 + 8*C + D, C
230 NEXT D
240 NEXT C
300 POKE 2604,28
400 FOR I=12288 TO 12295
410 READ C
420 POKE I,C
430 NEXT I
440 PRINT "@@@@@@@@"
500 DATA 3,6,12,30,3,6,12,24
```

This program will produce the same screen display as BARCODES, except that at the bottom of the display you will see eight lightning bolts.

HOW LIGHTNING WORKS:

The first part of the program (Lines 100 - 300) is the same as BARCODES.

The rest of the program alters the first 8 bytes in the table, and then prints something on the screen.

Lines 400 - 430

```
400 FOR I=12288 TO 12295
410 READ C
420 POKE I,C
```

describe the shape of the character "@". The program sets these 8 bytes to the values in the DATA line at the end of the program:

500 DATA 3,6,12,30,3,6,12,24

These values describe the shape of a lightning bolt:

GRID FOR LIGHTNING BOLT	BYTE VALUE	ENTRY IN SHAPE TABLE
......**	3	00000011
.....**.	6	00000110
....**..	12	00001100
...****.	30	00011110
......**	3	00000011
.....**.	6	00000110
....**..	12	00001100
...**...	24	00011000

Finally, line 500

500 PRINT "@@@@@@@@"

tells the computer to print eight "@" symbols. But since we have altered the shape table, the computer will display eight lightning bolts instead! If you press the "@" key on your keyboard, additional lightning bolts will be displayed.

It's a lot of work entering all of the codes to design your own set of characters. You can sometimes save yourself some work by borrowing from the shape tables in ROM. The following program will show you how to do this.

Before using this program, clear your computer completely. To do this, turn it off, wait ten seconds, and turn it back on.

ENTER THIS PROGRAM:

```
1 REM COPYSHAPES
100  BANK 14
200 FOR I=0 TO 511
210 P=PEEK(53248 + I)
220 POKE 12288+I, P
230 NEXT I
```

```
210 P=PEEK(53248 + I)
220 POKE 12288+I, P
230 NEXT I
300 BANK 15
310 POKE 2604,28
```

In its present form, this program is not too interesting. It copies the first 64 characters of the shape table to a new location and tells the computer to use this new shape table. Since the new table is like the old one, you will not see any differences. However, there are some simple modifications of this program which produce very interesting results!!

EXPERIMENT: Change Line 210 to

```
210 P=PEEK(53256 +I)
```

and run the program. (The program takes about 15 seconds to run). Whatever was on the screen will become unrecognizable. Press the letters "A", "B", and "C" on your keyboard. On your screen you will see

    BCD

What's going on here? Try pressing some other letters. Each time the screen will display "one-up" from the letter you pressed. If you press "P", the screen will display "Q"; if you press "X", the screen will display "Y"; and so on.

We got this result by modifying Line 210 to start at Location 53256, instead of 53248. The effect of this is to move the entire shape table by 1 character. This means that the shape for "B" is assigned to "A", the shape for "C" is assigned to "B", and so on.

EXPERIMENT: Modify COPYSHAPES to look like this (the only changes are Line 205, and Line 220):

```
1 REM WOM
100 BANK 14
200 FOR I=0 TO 511
205 D=D+2:IF D>16 THEN D=2
210 P=PEEK(53248 + I)
220 POKE 12297+I-D, P
```

```
230 NEXT I
300 BANK 15
310 POKE 2604,28
```

This program will turn all character shapes upside down. To invert a character shape, it is necessary to get each group of 8 bytes in the shape table into reverse order. For example

The shape codes for "Z" are: 126, 6, 12, 24, 48, 96, 126, 0.

The shape codes for an upside-down "Z" are: 0, 126, 96, 48, 24, 12, 6, 126.

Our changes in Lines 205 and 220 gets each group of 8 bytes into reverse order. Doing this involves a tricky combination of additions and subtractions. If you want to understand exactly how it works, trace the program through for the first few values of I.

There are other slight variations of the COPYSHAPES program which produce astounding effects. For more on this, see EXTRA TOPICS.

In order for the COPYSHAPES to work, the BANK command is necessary. We will explain the BANK in detail later. The main idea of the BANK command here is as follows: There are some portions of memory which are ordinarily inaccessible to the PEEK or POKE commands. The BANK command enables us to "get at" portions of memory that aren't accessible by PEEKing and POKEing. The Shape Table is an example of a portion of memory which normally is inaccessible. It resides in BANK 14. The BANK 14 command enables us to get at the Shape Table. (The "default BANK" for the computer is BANK 15).

CHAPTER 6
MEMORY SCANNER

The memory of your COMMODORE-128 is chock full of interesting information, and thus far we have explored only a small fraction of it. To help you to explore memory further, we are going to write a program called SNOOP, which makes it easy to scan through memory. We will use SNOOP a number of times in the rest of the book.

ENTER THIS PROGRAM:

```
1 REM SNOOP
110 INPUT "START AT";B
200 PRINT CHR$(147);"START= ";B
300 FOR LI=1 TO 10
400 FOR I=B TO B+7
410 P=PEEK(I)
420 IF P<32 OR P>95 THEN P=32
430 PRINT "   ";CHR$(P);
440 NEXT I
450 PRINT
500 FOR I=B TO B+7
510 P=PEEK(I)
520 P$=RIGHT$("   "+STR$(P),4)
530 PRINT P$;
540 NEXT I
550 PRINT
600 B=B+8
610 NEXT LI
620 GOTO 110
```

When you run the program, the following question will appear:

START AT?

The program is asking what location in memory you want to position yourself at. Type 16831 and press RETURN.

The computer will now display 80 bytes of memory, beginning at location 16831.

START= 16831

```
 C   O   M   M   O   D   O   R
67  79  77  77  79  68  79  82
 E       B   A   S   I   C
69  32  66  65  83  73  67  32
 V   7   .   0       1   2   2
86  55  46  48  32  49  50  50
 3   6   5       B   Y   T   E
51  54  53  32  66  89  84  69
 S       F   R   E   E       @
83  32  70  82  69  69  13  64
             (   C   )   1   9
32  32  32  40  67  41  49  57
 8   5       C   O   M   M   O
56  53  32  67  79  77  77  79
 D   O   R   E       E   L   E
68  79  82  69  32  69  76  69
 C   T   R   O   N   I   C   S
67  84  82  79  78  73  67  83
 ,       L   T   D   .       @
44  32  76  84  68  46  13  64
```

START AT?

The computer is displaying 80 bytes of memory, beginning with Location 16831. SNOOP displays the value in each byte-location. Additionally, whenever the value might possibly be an ASCII code for a character, that character is displayed above the line. (ASCII is a standard coding system used for representing letters, numbers, and other symbols in memory). This gives us some clues for understanding the codes in memory. For instance, in our present example you will recognize that this is the greeting that appears on the screen when you turn on the computer.

You are probably wondering what the rest of the codes are on the screen. We will find out more about that in the next chapter. Let's display another part of memory. Right now, the computer is asking you for another STARTING BYTE.

Type 18775 and press RETURN . On your screen you will see some information like this:

START= 18775

```
 D   I   V   I   S   I   O   N
68  73  86  73  83  73  79  78
     B   Y       Z   E   R
32  66  89  32  90  69  82 207
 I   L   L   E   G   A   L
73  76  76  69  71  65  76  32
 D   I   R   E   C       T   Y
68  73  82  69  67  212 84  89
 P   E       M   I   S   M   A
80  69  32  77  73  83  77  65
 T   C       S   T   R   I   N
84  67 200  83  84  82  73  78
 G       T   O   O       L   O
71  32  84  79  79  32  76  79
 N       F   I   L   E       D
78 199  70  73  76  69  32  68
 A   T       F   O   R   M   U
65  84 193  70  79  82  77  85
 L   A       T   O   O       C
76  65  32  84  79  79  32  67
```

START AT?

This section of memory holds error messages: "DIVISION BY ZER", "ILLEGAL DIREC", "TYPE MISMATC", "STRING TOO LON", and so on. Not everything makes obvious sense. For instance, the last letter seems to be missing from each error message, i.e., "DIVISION BY ZER","ILLEGAL DIREC", "TYPE MISMATC", "STRING TOO LON". What happened to the last letter? What do you think? (For the author's explanation, see the technical notes at the end of the book.)

As we proceed through this book, you will learn more about the way memory is organized, and the way in which codes are used, and this will help you to interpret the mysteries of the computer's internals.

HOW SNOOP WORKS

Most of SNOOP will be familiar to you from programs we have written earlier. We will just discuss the features that are

new or different.

Line 110

```
110 INPUT "START AT";B
```

obtains the location that you want to start at, and stores that location in the variable B.

Line 200

```
200 PRINT CHR$(147);"START= ";B
```

clears the screen and displays the starting location at the top of the screen.

The FOR - NEXT loop in lines 300 - 610

```
300 FOR LI = 1 TO 10
.
.
.
610 NEXT LI
```

prints 10 lines of information on the screen. Each line consists of 8 bytes of PEEKs. Each line is displayed in two ways. First, it is displayed translated into ASCII characters wherever possible. ASCII is a standard coding system, used by many computers, which assigns a number to each common symbol. For instance "A" is assigned the number 65, "B" is assigned 66, "C" is assigned 67. When the COMMODORE-128 stores characters in memory, it often uses ASCII codes (but not always!).

Lines 400 - 460 translates the codes from memory into ASCII symbols wherever this seems reasonable.

```
400 FOR I=B TO B+7
410 P=PEEK(I)
420 IF P<32 OR P>95 THEN P=32
430 PRINT "  ";CHR$(P);
440 NEXT I
450 PRINT
```

The "reasonable" range for ASCII codes is 32 - 95. Codes in this range stand for ordinary symbols. Codes outside this range generally do not. Line 420 converts all "unreasonable" values to 32, which is the ASCII code for a blank space.

```
420 IF P<32 OR P>95 THEN P=32
```

Line 430 prints the ASCII symbol for P, nicely formatted.

```
430 PRINT "   ";CHR$(P);
```

Only those values which translated into reasonable ASCII characters are displayed. Others are assigned a space.

Directly below this, each of the eight values is displayed in numeric form. The following lines of the program do that job.

```
500 FOR I=B TO B+7
510 P=PEEK(I)
520 P$=RIGHT$("   "+STR$(P),4)
530 PRINT P$;
540 NEXT I
550 PRINT
```

You may have wondered why there is a Line 110 in the program, but no Line 100. This is because we have reserved Line 100 for an additional feature which we will add to the program later in the book. The present version of the program can "get at" only 65,536 bytes, out of a total of approximately 192K bytes in the computer overall.

Now that you have SNOOP, you can look around memory on your own. Here are some suggestions for regions to look at:

STARTING BYTE	COMMENTS
17431	BASIC command vocabulary
18507	Error messages for disk, tape
63165	Miscellaneous messages from the computer
7168	Your program, as it is stored in memory

Try looking at some other regions as well. Most of the information will not be easy to interpret -- Commodore did not attempt to make memory easy to understand -- but you will discover many interesting patterns. In the next chapter, we will find out a great deal more about how to interpret the information in memory.

For many purposes, SNOOP is an excellent method for exploring memory. One of the nice features of SNOOP is that since it is written in BASIC, you can modify it for special purposes. For instance, if you wanted SNOOP to show only letters of the alphabet with no numbers or special symbols, you could accomplish this by modifying Line 420 of SNOOP.

There is another method for exploring memory which is built into your computer. This is the C-128 MONITOR. The MONITOR is explained thoroughly in the C-128 System Guide. We will also discuss the MONITOR in Appendix D.

Chapter 7
THE MAP OF MEMORY

You have now explored a number of interesting parts of memory. Memory is vast, and there is a great deal more that can be explored. To help you find your way around, and to help to to understand what you see, we are going to provide you with a map of memory. This map will show you many of the most important regions of memory. In later chapters, we will explore some of these regions in more detail.

The memory of a standard C-128 consists of approximately 196,000 locations, each of which holds one byte of information. (The fact that the C-128 has approximately 196,000 bytes of memory -- not 128,000 -- may come as a surprise to you. Doesn't the name of the computer -- "COMMODORE-128" imply that it has 128,000 bytes of memory? We will discuss this later in the chapter.) The computer uses this memory for many purposes. Here are some of the most important uses.

To track the screen. As we have already seen, the computer uses certain regions of memory to track what is on the screen.

To hold program and variables. When you are running a program in BASIC, the program and its variables are held in memory.

To hold reference information. The computer uses memory to hold reference information that it needs while it is running, for instance:

Information on the shapes of various letters and symbols that can be drawn on the screen.

Lists of error messages that can be displayed on the screen when something goes wrong.

Information on acceptable vocabulary and grammar for BASIC commands.

To hold current-status information. The computer uses portions of memory to track the current status of various activities, for instance:

What line of your BASIC program is currently being executed.

What key or keys have been most recently pressed on the keyboard.

Where the cursor is on the screen.

What time it is, according to the computer's internal clock.

What "peripherals" (disk drive, cassette, printer, ...) are currently communicating with the computer.

To provide a "scratch-pad" for temporary information. For instance:

When the computer encounters a GOSUB in a BASIC program, it needs a scratch area where it can leave a note to itself where to return to at the end of the subroutine. Most of these routines are short and perform very specific tasks, for instance:

When the computer is performing multiplication and divisions, it sometimes needs a scratch area to help it work out the calculations

When you are storing information on tape or disk, the computer needs an area where it can gather together the information and put it in the proper form, before sending it to the cassette or disk unit.

To hold special routines which help the computer to perform it's work. Most of these routines are short and perform very specific tasks, for instance:

Deciding what position to move the cursor to, each time you press a key on the keyboard.

Clearing the screen when you press SHIFT-CLR.

Keeping track of how far along the computer is in a FOR-NEXT loop.

Displaying the word "READY" on the screen, when a program is finished.

These routines are held in memory so that they can be called upon quickly. They are written in a high-speed language called "6502 Machine Language" (Your C-128 has a 8502 processor, but it works like a 6502). The vocabulary of this language is limited to only the most fundamental activities which the computer can perform. It is possible for a clever programmer to write extremely fast programs in this language. However it's hard work to write programs in machine language, as compared to BASIC. We will find out more about machine language later.
Those are some of the main ways in which memory is used. Shortly, we will map out what is where in memory. But before doing this, we need to introduce several important concepts concerning the computer's memory. These concepts will help us to discuss the layout of memory, with greater simplicity and clarity:

Kilobyte ("K"): 1 Kilobyte (1 K) is defined as exactly 1024 bytes. (The term "Kilobyte" is sometimes loosely used to mean 1000 bytes; but strictly speaking, it means exactly 1024 bytes). A standard C-128 computer comes equipped with 192K (approximately 192,000 bytes) of memory.

RAM memory: The 192K of memory in your C-128 consists of two types, "RAM memory" and "ROM memory". The easiest way to distinguish between the two types, is to consider what happens when you turn off your computer, and then turn it back on. When you turn the computer off, any programs and variables which had been in the computer are lost; the programs and variables do not reappear when you turn the computer back on. However, there is some "knowledge" which the computer never seems to lose. For instance, it remembers what greeting to display on the screen, when you turn it on. It also remembers how to execute BASIC. It remembers a collection of Error Messages to

display when you make a mistake.

These facts show that there are two kinds of memory in the computer.

The first kind of memory goes blank whenever the computer is turned off. This kind of memory is called "volatile memory", "Read-Write Memory", or "Random Access Memory (RAM)". We will refer to it as RAM, since this is the most common term for it. The C-128 has 128K of RAM (That's how it got the name "COMMODORE-128"). When the computer is off, RAM contains no information. When the computer is on, information may be recorded in RAM. Also, while the computer is on, information that is in RAM may be altered or erased. When the computer is turned off, everything that was in RAM is lost.

ROM memory: The second kind of memory is called "Read-Only Memory (ROM)". ROM has information permanently frozen into it. This information can be "read", but it cannot be altered or erased. That is why it is called "Read Only Memory". The information in ROM is there, even when the computer is off. The C-128 is equipped with approximately 64K of ROM. ROM holds information pertaining to: The C-128 "operating system"; BASIC; shapes of characters which can appear on the screen; CP/M. These will be discussed again later in the chapter.

RAM(0), RAM(1): RAM(0) refers to the first 64K of RAM. RAM(1)
refers to the last 64K of RAM.

BANKS: Although the C-128 has 192K of memory (128K of RAM and 64K of ROM), there are certain components of the machine which are unable to operate on more than 64K of memory at a time. Because of this, the designers of the C-128 had to invent a scheme which enables the computer to switch back and forth among various subsets of memory. The idea is that, at any moment, certain components can operate on only one 64K subset; but if the computer can cleverly switch back and forth between various subsets, these can effectively operate on the entire 192K of memory.

The engineers at Commodore identified 16 different subsets of the memory that are especially important in the ordinary

operation of the computer. Each of these subsets of memory is called a "bank".

Here are the main facts that you need to know about banks:

A bank is a 64K subset of memory. There are sixteen different banks. Each bank is a 64K subset of the entire 192K of RAM and ROM memory in the C-128. Some banks just consist of a portion of RAM. Other banks consist of a portion of RAM, and certain portions of ROM.

The sixteen different banks are referred to as Bank 0 thru Bank 15.

There are certain components of the C-128 which are unable to operate on more than 64K of memory at one time. That is the reason the "bank" concept is necessary.

Each bank consists of exactly 64K (65,536 bytes) of data. The memory locations in each bank are numbered from 0 thru 65,535.

When the computer is operating, it is normally set at Bank 15. However, when certain components of the computer need to "get at" portions of memory which are not in this bank, then it is possible to switch to a different bank for a while.

By cleverly switching between banks, it is possible for the computer to effectively operate on the entire 192K of memory, even though certain components can only deal with 64K at any particular moment.

Within BASIC, it is possible to switch banks, by means of the BANK command. E.g. BANK 3 switches the computer to bank 3; BANK 15 switches the computer to bank 15.

The most important banks are as follows:

BANK 0: Bank 0 consists of RAM(0) only (i.e., the first 64K of RAM). No ROM is included in BANK 0.

BANK 1: Bank 1 consists of RAM(1) only (i.e., the last 64K of RAM). No ROM is included in BANK 1.

BANK 15: Includes all the most important parts of ROM, with one exception. It also includes the first 16K of RAM. Bank 15 is the "default" bank for the C-128.

BANK 14: The same as BANK 15, except it includes the one important part of ROM omitted from Bank 15. More on this later.

One example of a capability of the computer which is limited to 64K at any moment, is the PEEK command. You may have noticed that the largest number accepted by the PEEK command is 65535. I.e., a command such as

```
PRINT PEEK(65536)
```

will give an error message. The largest number allowed by PEEK is 65535. Therefore, at any moment, the PEEK command can look at only 65536 (64K) different locations in memory. At any particular moment, PEEK can look at only the locations in the bank that is currently selected. (The default bank is Bank 15.)

However, we can effectively enable PEEK to cover all of memory, by switching banks. The following program illustrates how this can be done:

```
100 INPUT "WHAT BANK DO YOU WANT? (0 - 15)";B
110 INPUT "WHAT LOCATION IN THAT BANK";L
200 BANK B
210 P=PEEK(L)
220 PRINT "PEEK VALUE IS: ";P
```

Each time you run this program, it will ask you to INPUT a Bank number, and a location. It will then display the PEEK value for the Bank, and location, which you specify. By specifying different banks, you can PEEK into any part of memory, even though the PEEK command itself can only cover about 1/3 of memory at any moment.

Now, we are ready to survey memory region-by-region, to find out what goes on where. We will begin by surveying RAM(0) and RAM(1). Then we will discuss various parts of ROM. (All of the locations given are the standard locations

for the various kinds of information. Under some circumstances, the computer will relocate certain information to different locations in memory. We will give examples of this later in the chapter.

RAM(0):

Locations $0000 - $01FF (0 - 511): Reference information and current status information. This section of RAM(0) is crammed with tables and other data which is needed frequently:

The location in memory where your BASIC program begins.

Information on the regions in memory which are occupied by variables from your BASIC program.

Information on the status of your screen (e.g., the size of the "window" within the screen that is available for entry and display of your BASIC program).

What time it is, according to the computer's internal clock. Information on the keys most recently pressed on the keyboard.

Information on the exact staus of your BASIC program, while it is running: e.g., what line in the program is currently being executed.

Locations $0200 - $03FF (512 - 1023): More reference information, including locations of important machine language subroutines.

Locations $0400 - $07FF (1024 - 2047): Screen memory. As we have already learned, this area tracks what character is on each position of your screen. The first 1000 bytes of this region, correspond exactly to the first 1000 bytes on your screen. (The remaining 24 bytes in the region are unused).

Locations $0800 - $09FF (2048 - 2559): RETURN information for GOSUBs. When the computer executes a GOSUB routine, it must leave a note to itself where to RETURN to in your BASIC program, when the GOSUB

routine has been completed. The computer stores these notes in this region.

Locations $0A00 - $0AFF (2660 - 2815): More reference information. Information in this region pertains mainly to: Handling of peripherals; the exact way the computer behaves when you are editing a BASIC program (e.g., how fast the cursor blinks, whether key strokes will automatically repeat if you hold down a key for a certain period of time, whether <CTRL> - S will cause the computer to beep); locations of other regions of memory.

Locations $0B00 - $0DFF (2816 - 3583): Work areas for cassette, RS232 peripherals. When the computer uses peripherals such as a cassette, or a printer, it usually needs a "work area" in memory to act as a temporary holding area for data that is passing to or from a peripheral. This region is such a work area, for cassettes and RS232 peripherals.

Locations $0E00 - $0FFF (3584 - 4095): Sprite definition area. When you are defining sprites, the data which specifies their shape is stored in this region.

Locations $1000 - $10FF (4096 - 4351): Definitions for programmable function keys. If you use the KEY command in BASIC, to define strings for the various function keys (F1-F8), the definitions are stored in this area.

Locations $1100 - $12FF (4352 - 4863): Information relating to BASIC, especially graphics and sounds capabilities.

Locations $1300 - $1BFF (4864 - 7167): Unused, or reserved for special applications.

Locations $1C00 - $FEFF (7168 - 65279): Your BASIC program. Your program begins at location $1C00 and may continue as far as location $FEFF.

Locations $FF00 - $FFFF (65280 - 65535): Additional reference information.

RAM(1):

Except at the very beginning and end, RAM(1) is devoted exclusively to storing variables from your BASIC program.

Locations $0000 - $00FF (0 - 255): Same as corresponding locations in RAM(0). This information is so critical to most ordinary operations, that it is normally made available in both Bank 0 and Bank 1 (as well as in other banks).

Locations $0100 - $FEFF (256 - 65279): Variable storage. Numeric variables are stored in the lowest part of this area. Arrays are stored in the middle area. String information is stored in the highest area (with a little of the string information also stored in the lowest area). We will discuss this in detail in the chapter on variables.

Locations $FF00 - $FFFF (65280 - 65535): Critical reference information.

ROM:

Most of the important parts of ROM are accessible through Bank 15, so we will explain how Bank 15 is laid out:

Locations $0000 - $3FFF (0 - 16383): Same as ROM(0).

Locations $4000 - $AFFF (16384 - 45055): Machine language subroutines and tables pertaining to BASIC. These are the principle machine language subroutines and tables which enable the computer to execute BASIC commands and programs.

Locations $B000 - $BFFF (45056 - 49151): Machine language subroutines pertaining to the MONITOR. When you use the MONITOR, the machine language subroutines which enable it to operate, are in this region.

Locations $C000 - $CFFF (49152 - 53247): Machine language subroutines pertaining to the Editor. The Editor is what enables you to enter and edit programs in BASIC. The machine language subroutines for the Editor are in this region.

Locations \$D000 - \$DFFF (53248 - 57343): Tie-ins with peripherals. This area of memory helps the computer to "talk" with the keyboard, disk drive, joystick, modem, printer or other devices which are attached to the computer. It regulates the speed of transmission of data, it acts as a holding area for incoming and outgoing data, and it keeps things organized so that, for instance, signals from your joystick don't interfere with signals from the keyboard.

Locations \$E000 - F9FF (57344 - 63999): The KERNAL. This is a set of machine language routines for performing the most fundamental tasks, such as:

Deciding what position to move the cursor to, each time you press a key on the keyboard.

Clearing the screen, when you press SHIFT-CLR.

Updating the internal clock, in locations 160 - 162, every 1/60 of a second.

Interrupting your program, when you press STOP or STOP-RESTORE.

Controlling the speed at which data is sent to the printer.

Coordinating the various activities of the computer, so they don't get tangled with each other.

Locations \$FA00 - \$FFFF (64000 - 65535): Miscellaneous data. For example, tables used by the Editor, and a table of standard locations for certain machine language routines in the Kernal.

One important area of ROM is omitted from Bank 15, namely the Shape Table which we played with in Ch. 5. The Shape Table is accessible in Bank 14, starting in location \$D000 (53248).

This completes our map of memory. We shall explore some of these regions in more detail in later chapters.

Now that you are becoming more familiar with the computer's

memory, you can see that it is not always organized in a convenient manner for human beings. Information is usually expressed in codes, rarely in plain English. And the arrangement of the information in memory can seem rather unnatural. Why, for example, does screen memory begin at Location 1024? Why not an easy-to-remember location, such as 1000? And why does the computer express information in codes, instead of plain English?

These are very important questions, because they take us to the FIRST RULE OF COMPUTER SNOOPING:

THE FIRST RULE OF COMPUTER SNOOPING: *The computer is an alien form of lower intelligence.*

The computer is an intelligent machine; however its level of intelligence is much lower than that of human beings. Also the way in which it thinks is much different from the way in which human beings think. It is an "alien" form of intelligence. When you snoop inside a computer, you should not expect to find things arranged in a manner that is convenient for you. They are arranged in a manner that is convenient for the computer. About the only time that the computer makes things easy for you, is when it has to communicate with you:

When the computer is waiting to receive commands from you, it allows these commands to be entered in a language like BASIC, which is fairly easy for human beings to work with.

However, once you have entered a command, the computer quickly transforms that command to a form that is easy for the computer to work with.

The computer does most of its processing in ways that are alien to human thought. In general, the computer's methods are simple-minded and extremely tedious, by human standards. But they are methods which are convenient for the computer.

When the computer wants to communicate information back to you, it usually goes through a number of operations to convert that information to a form that is convenient for human beings.

It is useful to think of a computer as an "alien being", with limited intelligence, that can do work for human beings. It can communicate with human beings in a primitive way. But mainly it does its thinking in a way that is much different from that of humans.

The fundamental thought processes of computers are mainly quite simple, and by the end of the book, you will have become acquainted with most of them. After that, to become an advanced computer snooper is mainly detail work (**Warning**: a lot of detail work !!)

To conclude this chapter, let's take care of a few "loose ends" in our discussion of memory.

1. A moment ago, we asked why regions of memory do not have locations which are nice, round numbers. For instance, why does screen memory begin at Location 1024, rather than say 1000?

Part of the answer is that many of the locations are nice, round numbers to the computer, although not necessarily to us. To a human being, nice round numbers are: 100, 1000, 10000. These numbers are known as "powers of 10", i.e.

```
  100  =  10^2  =  10 * 10
 1000  =  10^3  =  10 * 10 * 10
10000  =  10^4  =  10 * 10 * 10 * 10
```

(The notation "10^4" means "4 10s multiplied together", i.e. 10 * 10 * 10 * 10)

Human beings find powers of 10 easy to remember and work with. Our entire number system is based on powers of 10 -- indeed it is known as "Base 10".

As was mentioned earlier, most computers are based on powers of 2, rather than powers of 10. Here is a list of some of the powers of 2.

```
4 = 2^2
8 = 2^3
```

```
   16 = 2^4
   32 = 2^5
   64 = 2^6
  128 = 2^7
  256 = 2^8
  512 = 2^9
 1024 = 2^10
 2048 = 2^11
 4096 = 2^12
 8192 = 2^13
16384 = 2^14
32768 = 2^15
65536 = 2^16
```

You will see these numbers frequently as you explore your computer. For instance

There are 8 bits in a byte

A byte can have 256 possible values

Screen memory normally begins at Location 1024

There are 65536 locations in memory

Why are powers of 2 so common in your computer? Computer engineers have discovered that by making heavy use of powers of 2 in the design of computers, they can build machines which are faster and cheaper. It would certainly be possible to design a computer where powers of 10 occur frequently, but the computer would probably not be as fast or efficient as power-of-two machines. A detailed explanantion would require a lot of mathematics, but the main idea is that modern computers make extensive use of switches. A switch is either on or off, which amounts to 2 possibilities. That is where the number 2 comes from. Since computers make extensive use of switches, powers of 2 arise naturally. (If someone were to design a computer which depended on a concept different from switches, powers of 2 might not show up frequently.)

2. We mentioned earlier that some of the standard locations in our map can be altered. A couple of examples will illustrate how this is done:

The standard location for a BASIC program is starting at Location 7168. The standard location is recorded in bytes 45-46 of memory. If the value of these bytes is altered, this will re-locate the starting location for BASIC programs.

The standard location for screen memory is starting at Location 1024. The standard location is recorded in byte 2604 of memory. If the value of that byte is altered to an appropriate value, this will re-locate the starting location for screen memory.

The information in bytes 45-46, or in byte 2604, is known as "master pointer" information. A master pointer "points" to the location in memory of something important. It is like a road sign that tells the computer the location of something important. You will find out more about master pointers in the remainder of this book. Major regions of memory can be re-located, by altering master pointers. (Warning, this can be tricky. Sometimes there are several master pointers that depend on one another. If you alter one without altering the others, you'll really screw things up!)

CHAPTER 8
PROGRAMS IN MEMORY

When you run a program in BASIC, a copy of that program is held in the computer's memory. However, the version in memory looks quite different from what you originally typed into the computer. In this chapter, we are going to find out what a program looks like in memory, and why it looks that way.

Clear your computer's memory completely. To do this, turn the computer off, wait ten seconds, and then turn it back on. This is to assure that nothing that you were doing previously will interfere with our experiments in this chapter.

Now, type the program SNOOP into the computer (or if you have a copy of it on cassette or disk, LOAD it).

RUN the program. When it asks you where to START AT, type 7168 and press RETURN. You will recall from our MAP in the last chapter, that location 7168 is the normal starting point of the area reserved for BASIC programs and variables. On your screen you will see the following display:

START = 7168

```
                                S
 0  13  28   1   0 143  32  83
 N   O   O   P
78  79  79  80   0  32  28 110
             "   S   T   A   R
 0 133  32  34  83  84  65  82
 T       A   T   "   ;   B
84  32  65  84  34  59  66   0
 9                           (
57  28 200   0 153  32 199  40
```

```
 1   4   7   )   ;   "   S   T
49  52  55  41  59  34  83  84
 A   R   T   =       "   ;   B
65  82  84  61  32  34  59  66
     I       ,               L
 0  73  28  44   1 129  32  76
 I       1               1   0
73 178  49  32 164  32  49  48
     Y                       I
 0  89  28 144   1 129  32  73
```

This is the first part of your program SNOOP as it held in memory. Parts of the program are easy to recognize: The REM statement at the beginning, the variable names, the words that are displayed on the screen. The other features of your program such as the line numbers and the command names are not so easy to recognize. Let's go over part of this screen byte by byte, and see how it relates to what's in the program SNOOP.

The first line in SNOOP is

1 REM SNOOP

In memory this shows up as

```
pointer to next   line
program line      one
 ┌──┐   ┌──┐   REM  space  S   N   O   O   P  end of line
13  28  1   0  143  32    83  78  79  79  80  0
```

The following diagram and comments will explain what each of the codes means:

13 28 1 0 143 32 83 78 79 79 80 0

The first two codes

13 28

are a "pointer" to the next line in the program. A "pointer" tells you the location of something important. This pointer tells where the next line of the program begins. This is calculated as follows: The location of the beginning of the next program line is:

$$13 + 256 * 28$$

which is equal to 7181. I.e., the next line of the program begins at location 7181. The purpose of pointers like these is to help the computer to find information quickly. We will find out more about pointers later.

The next two codes

1 0

give the line number. It is calculated as follows

$$1 + 256 * 0$$

$$= 1 + 0$$

$$= 1$$

So the line number is 1.

The next code

143

stands for REM. All of the command words in BASIC are abbreviated in memory as 1 - byte codes. Here are a few examples of the codes for BASIC command words:

FOR	129
NEXT	130
INPUT	133
REM	143
POKE	151
PRINT	160

A more complete chart is given at the end of this chapter.

The next code

32

is the ASCII code for a space. This indicates the space between REM and SNOOP in the program line.

The next 5 codes

83 78 79 79 80

are the ASCII codes for the letters S N O O P.

The final code

0

marks the end of the program line.

Let's figure out the next line of SNOOP.

110 INPUT "START AT";B

In memory this is represented by

```
pointer to next  line      INPUT
program line     110         |     space  "   S   T   A
┌──┐            ┌──┐         |
32 28           110 0       133    32    34  83  84  65

 R   T  space  A   T   "   ;
82  84   32   65  82  34  59  0
```

The first two bytes

32 28

are a pointer to the program line after this one. The location it points to is

32 + 28 * 256

= 32 + 7168

= 7200.

I.e., the next program line begins at Location 7200.

The next two bytes

110 0

give the line number. It is calculated as

```
     110 +  0 * 256
  =  110 +  0
  =  110
```

I.e., the line number is 110.

The next code,

    133

stands for INPUT. Whenever an INPUT command occurs in a BASIC program, it is abbreviated in memory as 133.

The next two codes

    32 34

stand for the blank space and quotation mark between INPUT and
START AT.

The next group of codes

    83 84 65 82 84 32 65 84

are the ASCII codes for

    START AT

The next two codes

    34 59

stand for the right quotation mark, and the semicolon.

The next code

    66

is the ASCII code for the the letter "B". This is how the variable B is represented in memory.

The final code

0

marks the end of the program line.

If you would like to learn more about how BASIC programs are stored in memory, use SNOOP to look at more examples of BASIC commands as they are stored in memory. Also, we suggest that you experiment with using POKE commands to alter a program that is in memory. By trying out various POKE's you can find out in detail what the purpose is of every code in memory. As you are exploring, here are a couple of "fine points" that you should be aware of:

Normally, the BASIC program area starts at Location 7168. (In the next chapter, we will find out how that starting point can be relocated.) The first byte of this area is always set to 0. Your program always begins at the second byte, i.e. location 7169.

If the first two bytes of a program line are

0 0

then this really isn't a program line at all. Instead, it is a signal that the end of the program has been reached. This is how the computer marks the end of a program. If you are examining a program in memory, and you arrive at a program line which begins with 0 0, you are done, you have reached the end of the program.

We are now going to illustrate the power of the POKE with a couple of examples of programs that are transformed by a few POKE's.

First, we will try out an example of a program that re-writes itself.

ENTER THIS PROGRAM EXACTLY AS WRITTEN:

```
1 REM REWRITE
100 PRINT "JOHN HAD"
110 PRINT "GREAT BIG"
```

```
120 PRINT "WATERPROOF"
130 PRINT "BOOTS ON"
200 FOR I = 7168 TO 7280
210 IF PEEK(I) = 153 THEN POKE I,143
220 NEXT I
```

Make sure that you have entered this program exactly as it appears in this book. Do not leave out the REM statement or revise any of the program lines from how they are shown in this book, or the program may not work.

When you run this program, it will do two things:

First, it will display a message on the screen.

Second, it will rewrite lines 110 - 140. After you have run the program, we will run it again, and you will discover that it has changed.

RUN THE PROGRAM

On your screen you will see a message:

```
JOHN HAD
GREAT BIG
WATERPROOF
BOOTS ON
```

The program has also rewritten itself. To prove this,

RUN THE PROGRAM AGAIN

This time, no message will appear on the screen. What has happened?

To find out has happened, LIST the program. It will look like this:

```
1 REM REWRITE
100 REM "JOHN HAD"
110 REM "GREAT BIG"
120 REM "WATERPROOF"
130 REM "BOOTS ON"
200 FOR I = 7168 TO 7280
210 IF PEEK(I) = 153 THEN POKE I,143
```

```
220 NEXT I
```

The four PRINT commands that were in lines 100 - 130 have been changed to REM statements. That is why when you ran the program the second time, nothing appeared on the screen. REWRITE has rewritten itself!

HOW THE PROGRAM WORKS:

Lines 200 - 220 scan the area where the program is, and look for any occurrences of the code 153. This is the computer's code for the PRINT command. Whenever it finds one of these codes, Line 210

```
210 IF PEEK(I) = 153 THEN POKE I,143
```

changes it to 143, which is the code for REM. This is how all of the PRINTs are changed to REMs.

This next program uses POKE's to make itself "invisible".

ENTER THIS PROGRAM EXACTLY AS WRITTEN:

```
1 REM INVIS
100 PRINT "HI MOM!"
110 PRINT "HERE I AM!!"
200 POKE 7169,32: POKE 7170,32
```

When you run this program, it will display a message on the screen. It will also perform some "magic" on itself so that it cannot be listed, except for the first line.

RUN the program. On your screen you will see

```
HI MOM!
HERE I AM!!
```

Now LIST the program. All that will appear is

```
1 REM INVIS
```

Where is the rest of the program? Well, it was not erased from memory. To prove this, type RUN and press RETURN. Once again the message

HI MOM!
HERE I AM!!

will appear. This proves that the program is still operating. You just can't see it anymore!

HOW INVIS WORKS:

The trick to the program is in lines 200

```
200 POKE 7169,32: POKE 7170,32
```

This command POKEs new values into Locations 7169 and 7170, which are the first two bytes of your program. As we discovered earlier, the first two bytes of the program contain a "pointer", which tells the computer where the next line of the program begins. The computer needs this information when you want to LIST the program. The pointer information helps the computer to locate each line of your program in memory.

The POKE in Line 200 altered some of this pointer information. The effect of this was to confuse the computer as to where the second line of the program is. We altered the pointer so that when the computer looked for the second line of the program, it was directed to an area of memory that has nothing but 0's. When the computer saw those 0's, it believed that it had arrived at the end of the program. So the computer quit LISTing the program after the first line.

Now, your original program has not been erased at all. Each of the commands is still in memory, just as it was. And because of this, the computer can still execute the program. It happens that the computer does not need much pointer information to execute a program. So, although the altered pointer affects the ability of the computer to LIST the program, it does not affect its ability to execute the program.

If you have a disk drive or cassette recorder, you can still SAVE, and re-LOAD the program. When you re-LOAD it, you will find that the entire program will LIST again. This is because the computer will automatically set the pointers in proper order each time the program is LOADed. However, if you run the program again, it will once again become invisible.

To conclude this chapter, we direct you to the Appendices where you will find a chart that shows the codes used in "tokenizing" or abbreviating BASIC 7.0 statements, commands and functions. In the next chapter, we will find out more about pointers, and why the computer likes to use them.

CHAPTER 9
POINTERS

In the last chapter, we found out that when a program is held in memory, it contains many "pointers". A "pointer" is a piece of information which tells the computer where something is located. At the beginning of each line of the program, there is a pointer which tells the computer where the next program line begins in memory.

This is only one of many situations where the computer uses pointers. Memory is filled with thousands of pointers. In this chapter, we will find out why there are so many pointers, and what they are used for. We will see that there are two main reasons why the computer uses pointers:

First, pointers help the computer to find information quickly.

Second, pointers help the computer to arrange information more efficiently.

To begin, let's find out what the pointers in program text are used for.

Each line of the program begins with a pointer. That pointer tells the computer where the next program line begins. How is this information useful to the computer? Well, when a program is running, and the computer encounters a GOTO command, the pointers help it to find the line of the program that it needs. Instead of scanning the entire program, it merely follows the chain of pointers within the program. Each time it arrives at a new line in the program, it looks at just the Line Number. If that's not the line number which is needed, the computer follows the pointer to the next line of the program. Thanks to the pointers, the computer can find the beginning of each line very quickly, it does not have to get

bogged down "reading" the entire text of each line. This helps the computer to find the line number it needs very quickly.

Let's find out what else pointers are used for. The following program will enable you to look at several very important pointers in memory. Clear your computer completely by turning it off, waiting 10 seconds, and then turning it back on. Then

RUN THIS PROGRAM:

```
1 REM POINTERS
100 P=PEEK(45) + 256*PEEK(46)
110 PRINT "BASIC PROGRAM STARTS AT";P
200 P=PEEK(47) + 256*PEEK(48)
210 PRINT "VARIABLE REGION STARTS AT";P
300 P=PEEK(57) + 256*PEEK(58)
310 PRINT "VARIABLE REGION ENDS AT";P
```

On your screen, you will see some information like this:

```
BASIC PROGRAM STARTS AT 7169
VARIABLE REGION STARTS AT 1024
VARIABLE REGION ENDS AT 65280
```

The computer is telling you three important locations in memory.

The first line on the screen tells you where the region for BASIC programs begins. This is already familiar to you. Normally this region begins at Location 7169.

The second line tells you where the region for variables begins in RAM(1). In our illustration, it begins at location 1024.

The third line tells you where the region for variables ends in RAM(1). In this illustration, the end is Location 65280. So, the computer has reserved the region 1024 - 65280 for BASIC variables.

The computer got this information from three pointers in memory.

The pointer in Locations 45 - 46 tell where the region for BASIC programs begins.

The pointer in Locations 47 - 48 tells where the region for BASIC variables begins in RAM(1).

The pointer in Locations 57 - 58 tells where the region for BASIC variables ends in RAM(1).

In each case, the pointer is stored in two bytes of memory. The value of each pointer is calculated as follows:

VALUE OF FIRST BYTE + (256 * VALUE OF SECOND BYTE)

So for instance, if

VALUE OF THE FIRST BYTE = 1
VALUE OF THE SECOND BYTE = 28

then

VALUE OF THE POINTER = 1 + (256 * 28)
= 1 + 2048
= 7169

This formula is typical of how most pointer values are calculated. The formula seems tedious to calculate, but actually it is a very easy kind of formula for the computer to calculate. The mathematical reasons for this are beyond the scope of this book, but the main idea is that 256 in Base Two is

100000000

and this is an easy number for the computer to multiply with. And it's easy for roughly the same reason that its easy for a human being to multiply a number by one thousand. (What's easy for a computer is not necessarily easy for humans, and vice versa!)

If you would like to learn more about why computers find pointer values like this easy to calculate, see the reading list in Chapter 16, CONCLUSION.

The pointers we have just looked at are useful to the computer for two reasons.

First, they help the computer to find important regions of memory quickly. For instance, if the computer needs to scan the variables in memory, it can look up the the pointer in Locations 47 - 48 to find out where the region for variables begins. The pointer helps the computer to find the region quickly.

Second, the pointers make it very easy for the computer to rearrange memory. Suppose for instance that the computer needs a large chunk of RAM for storing some huge graphic images. It could reserve some RAM for this purpose by (for instance) increasing the value of the pointer in Locations 47-48 (beginning of the variable region in RAM(1)). The effect of this would be to allow part of what is ordinarily the variable region, to be used for something else.

We call pointers like these "master pointers". Master pointers tell the computer where important areas of memory are located.

There is a master pointer which tells the computer where screen memory is. If the value of that pointer is changed, screen memory is shifted to a different location.

There is a master pointer which tells the computer where the Shape Table is. If the value of that pointer is changed, the computer will use another region of memory for its shape table.

There are master pointers which tell the computer where there is additional space for variables.

There are a large number of master pointers which tell the computer where various machine language routines are located in memory.

When you turn on the computer, the master pointers are set to standard values. But it is possible to modify them. For instance, if someone writes a program for the COMMODORE-128 which does not use BASIC, the program could alter some of the master pointers for BASIC and thus obtain more space to use in memory.

Pointers are easy for the computer to work with, but human beings generally find them hard to get used to. To help you

get adjusted to pointers, it is useful to look at some simple examples. The following examples use systems of pointers that are similar to what you find in the computer, but they are presented in a form that is a little more pleasant for human beings.

Here is a sample of some data that uses pointers:

<BEG>THIS IS THE STORY <051><BEG>I DREAMT OF <082> OF LITTLE RED RIDING HOOD <094>FLYING <113>THREE TURKEYS <128>TO ALASKA <144>AND BB WOLF<END>IN A HELICOPTER<END>

There are two different messages contained in this data. The first one is:

THIS IS THE STORY OF LITTLE RED RIDING HOOD THREE TURKEYS AND BB WOLF

The second one is

I DREAMT OF FLYING TO ALASKA IN A HELICOPTER

In one chunk of data, there are two different messages weaved together, by means of pointers. Let's find out how this was done.

The data is 163 characters long altogether. Along with the actual messages, there are some **markers** that tell you how the information is organized.

The <BEG> markers

The <END> markers

The pointers -- markers consisting of brackets with a number inbetween

The <BEG> markers mark the beginning of a message. The <END> markers mark the end of a message. The pointers indicates that a message leaves off in a certain place and picks up at a later location. For instance, in the first line, we see

<BEG>THIS IS THE STORY <051>

The pointer <051> says that this message is leaving off here, and continues at position 51. Position 51 is at the beginning of the second line

OF LITTLE RED RIDING HOOD <094>

This piece of the message ends with another pointer, <094>. This means that the message leaves off here, and continues at position 94, which is

THREE TURKEYS <128>

That piece of the message ends with a pointer, <128>. This means that the message leaves off here, and continues at position 128, which is

AND BB WOLF<END>

This piece of the message ends with <END>, which signifies the end of the message.

So what we have here is one message which has been snipped into four separate parts. The parts are connected together by means of pointers. I.e.

THIS IS THE STORY

points to

OF LITTLE RED RIDING HOOD

which points to

THREE TURKEYS

which points to

AND BB WOLF

The second message

I DREAMT OF FLYING TO ALASKA IN A HELICOPTER

has been snipped into four pieces, which are connected by means of points. The four pieces are

I DREAMT OF

FLYING

TO ALASKA

IN A HELICOPTER

These four pieces are connected by means of pointers. The following diagram summarizes how the pointers connect everything together.

<BEG> THIS IS THE STORY <051><BEG> I DREAMT

<082> OF LITTLE RED RIDING HOOD <094>

FLYING<113> THREE TURKEYS <128> TO ALASKA

<144> AND BB WOLF <END>IN A HELICOPTER

<END>

So what we have here are two messages, each of which have been snipped into little pieces, and then weaved together. Pointers are used to keep the right pieces of each message connected. The <BEG> and <END> markers are used to show the start and end of each message.

One of the advantages of pointers is that they help you to use space efficently. Suppose you have a message with 10,000 characters, and you do not have a single free area in memory that is big enough for the entire message. However, you do have ten smaller areas in various parts of memory, that together do provide enough space. Well, you can snip the message into 10 smaller pieces, store each piece in a different part of memory, and use pointers to connect the 10 pieces together.

Another advantage of pointers is dealing with changes in a message. Let's suppose that we want to remove the phrase

THREE TURKEYS

from the Little Red Riding Hood message. Here's how to do it:

<BEG>THIS IS THE STORY <051><BEG>I DREAMT OF <082>OF LITTLE RED RIDING HOOD <128>FLYING <113>THREE TURKEYS <128>TO ALASKA <144>AND BB WOLF<END>IN A HELICOPTER<END>

All that we did is change the pointer in the second line, after the word HOOD. The pointer used to be <094>, which pointed to the phrase

THREE TURKEYS

We changed it to <128>, so that it now points to

AND BB WOLF

In other words, we adjusted a pointer, so that it points past the phrase we wanted to omit. Now when you trace the pointers, you will get the following message

THIS IS THE STORY OF LITTLE RED RIDING HOOD AND BB WOLF

The phrase THREE TURKEYS is still in the data, but it has been deleted from the message, since the pointers skip past it.

You can also use pointers to quickly insert new data in a message. See if you can figure out what happens in this example:

<BEG>THIS IS THE STORY <051><BEG>I DREAMT OF <082>OF LITTLE RED RIDING HOOD <164>FLYING <113>THREE T
URKEYS <128>TO ALASKA <144>AND BB WOLF<END>IN A HELICOPTER<END>A NEAT OLD GRANDMA <128>

The Little Red Riding Hood message has now become

THIS IS THE STORY OF LITTLE RED RIDING HOOD A NEAT OLD GRANDMA AND BB WOLF

Here's how we got this result:

At the end of the data, we added the phrase A NEAT OLD GRANDMA

We adjusted the pointer after HOOD to <164>, which points at the beginning of the new phrase A NEAT OLD GRANDMA

We set the pointer at the end of the new phrase to <128>, which points to the beginning of the phrase AND BB WOLF

The convenience of this is that we did not have to rewrite the old part of the message. This is a great advantage when you are dealing with long messages.

The pointers and markers that you will find in the COMMODORE-128 are similar to the ones in these examples. However, the markers are not usually as easy to recognize and interpret as it was here. That's because what is easy for the computer is not necessarily easy for human beings.

CHAPTER 10
VARIABLES AND AN INTRODUCTION TO BANKS

In the last chapter we saw what a program looks like in memory. Programs use variables. In this chapter we will find out what variables look like in memory. While doing this, we will also become aquainted with a feature known as Banking, which helps the computer in managing large amounts of information in memory.

KINDS OF VARIABLES

Your COMMODORE-128 allows you to use several kinds of variables, for various purposes:

Floating point variables are probably most familiar to you. Examples of floating point variables are:

A , Q , A7 , WZ , I

A floating point variable may hold any kind of number, positive or negative, whole number or decimal. Examples of allowable values are:

5 , 0 , 9999888 , -197.325 , 59.32 , 177324E+13

The last number

177324E+13

means 177324 with thirteen 0's tacked on to the end, i.e.

1773240000000000000

Notation like this is known as "exponential notation". Exponential notation is a convenient way for writing very large or very small numbers. For instance,

1.7332E-10

means

.00000000017332

To find out more about notation like this, see your COMMODORE-128 SYSTEM GUIDE.

Integer variables may have only integers (whole numbers) as values. Integer variables always end with a '%'. Examples of integer variables are:

A% , Q% , A7% , WZ% , I%

Examples of allowable values are:

5 , 0 , 17993 , -1533

String variables may hold strings of symbols of any kind. String variables always end with a '$'. Examples of string variables are:

A$, Q$, A7$, WZ$, I$

Examples of allowable values are

"MRFL@X" , "123998" , "Z198&().XAP" , "COMBAT BOOTHS"

An **array** is a group of variables which is defined in one fell swoop. An array is set up by means of a DIM command. For instance,

DIM QJ$(15)

tells the computer to set up 16 different variables, whose

names are:

QJ$(0) , QJ$(1) , QJ$(2) , QJ$(3) , ... , QJ$(14) , QJ$(15)

Each of these sixteen variables is a separate string variable. Each one may have its own value.

You may use the DIM command to define arrays of floating point variables, arrays of integer variables, or arrays of string variables.

For additional information on variables, see your COMMODORE-128 SYSTEM GUIDE.

The following program will allow you to INPUT a number into a variable called AB%. Then the program will display how the variable looks in memory.

```
1REM VARLOOK1
100 BANK 1
110 INPUT "VALUE FOR AB%";AB%
200 B=PEEK(47) + 256*PEEK(48)
300 FOR I=B TO B+6
310 PRINT PEEK(I);
320 NEXT I
400 PRINT:PRINT:GOTO 110
```

When you run this program, it will ask you to enter a number. That number will be stored in the variable AB%. Then the program will display the part of memory in which AB% is stored.

RUN THE PROGRAM

The program will ask you "VALUE FOR AB% ?". Type 259 and press RETURN. The following information will appear on the screen:

```
193 194  1  3  0  0  0
```

This is what AB% looks like in memory.

The following will explain what each of the codes means:

The first two codes

193 194

are the name of the variable. 193 stands for "A", and 194 stands for "B". Here is how the codes 193 and 194 are derived:

```
The ASCII code for "A" is  65
                        + 128
                        -----
                          193

The ASCII code for "B" is  66
                        + 128
                        -----
                          194
```

The computer adds 128 to the ASCII codes to signify that this is an "integer variable". An "integer variable" is a variable that ends with a "%". An integer variable is allowed to have only integer values such as 1, 2, 3, -1, -2, -3, or 0.

The next two codes

1 3

represent the value of the variable. If the value of the variable is positive, the value of the variable is calculated as

(256 * FIRST CODE) + (SECOND CODE)

In this example, the value works out to

(256 * 1) + 3

= 256 + 3

= 259

The last three codes

0 0 0

are unused.

Let's try a few more examples. Try entering each of these numbers:

```
 260
 519
1097
   0
```

You will get the following information on the screen:

```
VALUE FOR AB%? 260
 193 194   1   4   0  0  0

VALUE FOR AB%? 519
 193 194   2   7   0  0  0

VALUE FOR AB%? 1097
 193 194   4  73   0  0  0

VALUE FOR AB%? 0
 193 194   0   0   0  0  0
```

In each case the variable AB% looks the same, except for the third and fourth bytes, which show the value in the variable.

Now, let's find out what AB% looks like when it is holding a negative value. Try the following examples:

```
-1
-2
-3
```

You will get the following information on the screen:

```
VALUE FOR AB%? -1
 193 194 255 255  0  0  0

VALUE FOR AB%? -2
 193 194 255 254  0  0  0

VALUE FOR AB%? -3
 193 194 255 253  0  0  0
```

If you try a few more examples of negative numbers, the pattern will be clear. This method of representing negative numbers seems strange, but it is quite common with computers. Computers can calculate very efficiently with negative numbers when using this representation. If you would like to learn more about it, it is known as "Two's complement notation", and it is discussed in most books on machine language programming or beginning computer science (see the suggested reading in Ch. 16, CONCLUSION).

HOW VARLOOK1 WORKS

Line 100

```
100 BANK 1
```

tells the computer we want to operate on BANK 1. BANK 1 is RAM(1) (i.e. the last half of RAM), which is where variables are stored.

Line 110

```
110 INPUT "VALUE FOR AB%";AB%
```

allows the user to INPUT a number, which is then stored in the variable AB%. The '%' signifies that the variable is an "integer variable".

Line 200

```
200 B=PEEK(47) + 256*PEEK(48)
```

calculates the beginning of the region where variables are stored. Locations 47 - 48 hold the pointer which points to the beginning of this region. B is the value of the pointer.

Variables (with the exception of array variables) are stored in this region in the order in which they first appear in the program. AB% is the first variable to appear in our program. So it will occur first in the region.

Each variable uses 7 bytes in memory. Lines 300 - 320

```
300 FOR I=B TO B+6
310 PRINT PEEK(I);
```

```
320 NEXT I
```

display the values in the first 7 bytes of the region. This will be the information on the variable AB%.

Line 400

```
400 PRINT:PRINT:GOTO 110
```

skips two lines on the screen, and takes you back to Line 110, to INPUT another value.

Different variable types are stored in memory in different ways. We have seen how integer variables are stored. Now let's find out how "floating point" variables are stored. A "floating point" variable is simply the ordinary kind of variable used to store numbers of all kinds, including decimals. Examples of floating point variables are: A , B , I , Z , A7 , Q9 , PQ , AB.

To see how floating point variables are stored in memory, we can use VARLOOK1, with just two small changes in the program. We will change the program so that it uses the variable AB instead of AB%. AB is a floating point variable, since it does not have a "%" at the end, the way AB% does.

CHANGE VARLOOK1 TO LOOK LIKE THIS:

```
1REM VARLOOK2
100 BANK 1
110 INPUT "VALUE FOR AB";AB
200 B=PEEK(47) + 256*PEEK(48)
300 FOR I=B TO B+6
310 PRINT PEEK(I);
320 NEXT I
400 PRINT:PRINT:GOTO 110
```

This version is the same as the old version, except that we removed the "%"s in line 110.

Now run the program. When it asks you for a number, type 0 and press RETURN. On your screen you will see the following codes:

```
VALUE FOR AB? 0
 65 66  0  0  0  0  0
```

This is similar to what you saw earlier with AB%. Here are the differences:

The first two codes name the variable as before, except that the value of 128 is no longer added. If the value of 128 is not added, this tells the computer that this is a floating point variable. I.e.

65 66

means "floating point", and

193 194

means "integer".

The remaining 5 codes

0 0 0 0 0

represent the value of the variable.

Let's see how some other values are stored in AB%. Try each of these values:

```
 1
 2
 3
 4
 8
16
  .1
  .2
```

You will get the following information on your screen:

VALUE FOR AB? 1
65 66 129 0 0 0 0

VALUE FOR AB? 2
65 66 130 0 0 0 0

```
VALUE FOR AB? 3
 65 66 130 64  0  0  0

VALUE FOR AB? 4
 65 66 131  0  0  0  0

VALUE FOR AB? 8
 65 66 132  0  0  0  0

VALUE FOR AB? 16
 65 66 133  0  0  0  0

VALUE FOR AB? .1
 65 66 125 76 204 204 205

VALUE FOR AB? .2
 65 66 126 76 204 204 205
```

In each case, the last 5 codes on a line represent the value that is in AB. As you can see, the pattern is strange! The rules which are used for representing values are too complicated to be discussed in this book. However, if you want to know them, you should be able to figure them out by trying some examples.

This brings us to the

SECOND RULE OF COMPUTER SNOOPING:
You can learn a lot about how your computer works by running experiments.

This rule is important for several reasons.

First, you will discover, if you haven't already, that good technical documentation is hard to find (for the COMMODORE-128 or almost any other computer). It's difficult to find documentation that is easy to understand. It's difficult to find documentation that explains all technical details. Also, you will discover that documentation can be inaccurate or incomplete. However it's often easy to figure out what you need to know by running some experiments.

Second, it reminds us that computers have a low order of intelligence. They tend to do their work in tedious, simple-minded ways. This makes it possible to understand almost everything they do, if you have enough patience.

Third, experimenting is fun! And, as long as you do not open your computer, your experiments can cause no harm.

Now, returning to the problem at hand, here are some suggested numbers to try out, to figure out how numbers are represented in floating point variables. (Try out these numbers in the order listed):

```
 1, 2, 4, 8, 16, 32, 64, 128, 256, 512,1024
-1, -2, -4, -8, -16, -32, -128
-1, -2, -3, -4, -5, -6, -7, -8
 1, .5, .25, .125, .0625, .03125
-1, -.5, -.25, -.125, -.0625, -.03125
 1,10,100,1000,10000,100000,1000000,1000000
```

Another way to approach the problem is to set up a variable in memory, find its location in memory, and then POKE some values into it, and see what happens. If you would like to do this, see the program VARPOKE in Appendix A, EXTRA TOPICS.

Now, let's find out what a "string variable" looks like in memory. A string variable is simply any variable that ends with a "$". String variables can be used to hold any kind of information, numeric or otherwise.

The COMMODORE-128 uses a fairly complicated scheme to organize string variables in memory. This scheme enables the COMMODORE-128 to accomodate strings of various lengths, anywhere from 0 to 255 characters. The method involves splitting up the variable into two parts: The SYSTEM BLOCK and the DATA BLOCK.

The SYSTEM BLOCK holds the name of the variable, the number of characters of data in the string, and a pointer to the DATA BLOCK. The SYSTEM BLOCK is held in the same part of memory as the information integer variables and floating point variables.

The DATA BLOCK holds the actual data in the variable. The DATA BLOCK is stored in the upper end of he region for BASIC (The last byte of upper end is normally location 65280).

The following program will allow you to see both parts of a string variable AB$.

ENTER THIS PROGRAM:

```
1REM VARLOOK3
100 BANK 1
110 INPUT "VALUE FOR AB$";AB$
200 B=PEEK(47) + 256*PEEK(48)
300 FOR I=B TO B+6
310 PRINT PEEK(I);
320 NEXT I
400 PRINT:PRINT
500 C=PEEK(B+2)
510 B1= 256*PEEK(B+3) + PEEK(B+4)
520 PRINT "DATA BLOCK STARTS AT";B1
600 FOR I=B1 TO B1+C-1
610 PRINT PEEK(I);
620 NEXT I
700 PRINT:PRINT:PRINT:GOTO 110
```

RUN the program. When it asks you

VALUE FOR AB$

type **ABCDEF** and press **RETURN**. Some information like this will appear on the screen.

```
VALUE FOR AB$? ABCDEF
 65 194  6 248 254  0  0

DATA BLOCK STARTS AT 65272
 65  66  67  68  69  70
```

The first line of numbers is the SYSTEM BLOCK for AB$. The first two codes

65 194

give the name of the variable. This time, 128 has been added to the second code only. This is the computer's way of indicating that this is a string variable, rather than an integer variable or a floating point variable.

The next code

6

is the number of characters in the variable. This says that AB$ is 6 characters long.

The next two numbers

248 254

are a pointer to the start of the DATA BLOCK. In this illustration, the DATA BLOCK starts at

```
    248 + 256 * 254
=   250 + 65024
=   65272
```

The last two bytes in the SYSTEM BLOCK

0 0

are not used.

The last line

65 66 67 68 69 70

are the values in the DATA BLOCK (Locations 65272 - 65277 in this example). These are the ASCII codes for the data in the variable.

Let's try entering new data into AB$. Right now the computer is asking

VALUE FOR AB$?

type **GHI** and press **RETURN**. Some information like this will appear on the screen.

```
VALUE FOR AB$? GHI
 65 194  3 243 254  0  0

DATA BLOCK STARTS AT 54267
 71  72  73
```

Notice that this time the DATA BLOCK begins in a lower location in memory than before. The first time, our DATA

BLOCK started at Location 65272. This time, the DATA BLOCK begins at 65267. If you INPUT data into AB$ again, you will find the DATA BLOCK starting at a lower location again. The computer always tries to store DATA BLOCKs in the highest area of the region for BASIC. It "starts at the top, and works its way down". At the end of this chapter, we will summarize how variables are stored in memory.

HOW VARLOOK3 WORKS

The first part of the program is similar to VARLOOK1 and VARLOOK2:

```
100 BANK 1
110 INPUT "VALUE FOR AB$";AB$
200 B=PEEK(47) + 256*PEEK(48)
300 FOR I=B TO B+6
310 PRINT PEEK(I);
320 NEXT I
400 PRINT:PRINT
```

It allows the user to INPUT some data into AB$. The program then finds the SYSTEM BLOCK for AB$. To do this, it goes through the same calculations as finding the information for an integer variable or floating point variable.

In Lines 500 and 510 the program extracts some information from the SYSTEM BLOCK. In Line 500

```
500 C=PEEK(B+2)
```

it finds out the number of characters in the DATA BLOCK.

In Line 510

```
510 B1= 256*PEEK(B+3) + PEEK(B+4)
```

it examines the pointer to the DATA BLOCK, and stores the starting location of the DATA BLOCK in the variable B1. In Line 520, it PRINTs that location.

```
520 PRINT "DATA BLOCK STARTS AT";B1
```

Lines 600 - 620

```
600 FOR I=B1 TO B1+C-1
610 PRINT PEEK(I);
620 NEXT I
```

display the contents of the DATA BLOCK.

Line 700

```
700 PRINT:PRINT:PRINT:GOTO 110
```

skips a few lines on the screen and then takes you back to Line 110.

SUMMARY

There is a region of memory in RAM(1) which is reserved for storing variables.

The low end of the region begins is given by the pointer in Locations 47 - 48. Normally the low end of the region is 1024.

The high end of the region is given by the pointer in Locations 57 - 58. Normally the high end of the region is Location 65280.

Integer variables, floating point variables, and SYSTEM BLOCKs for string variables are stored in the low end of the region. For each variable, 7 bytes of information are used. The meaning of the information depends on the kind of the variable.

DATA BLOCKs for string variables are stored at the high end of the region. Each DATA BLOCK can require from 1 to 255 bytes, depending on the amount of data in the string variable.

As the computer processes integer variables, floating point variables, and string variables, more and more of the low end of the region is used. Also, as the computer processes string variables, more and more of the high end of the region is used. As the low end and high end are used more and more, they grow toward each other.

If the low end and high end of the variable region "collide", the computer will attempt to rearrange data in the entire region

as neatly as possible, in order to reclaim some usable space. The following program will demonstrate what happens.

RUN THIS PROGRAM:

```
1 REM VARWHERE
100 DIM A$(300): BANK 1
110 FOR I=1 TO 254
120 P$=P$ + CHR$(I)
130 NEXT I
200 R1= INT(300*RND(1))
210 R2= 200 + INT(50*RND(1))
220 A$(R1)= LEFT$(P$,R2)
230 PRINT PEEK(53) + 256*PEEK(54)
240 GOTO 200
```

This is a "do-nothing" program which randomly adds and removes data from the various elements of the array A$(). The program tends to add more data than it removes, and gradually A$() will accumulate more and more data. Eventually, memory capacity will be exceeded, and you will will get an OUT OF MEMORY error.

While the program is running, it will give you frequent readouts on the usage of variable memory. Line 230

```
230 PRINT PEEK(53) + 256*PEEK(54)
```

displays the value of a pointer which shows the lowest location in memory in use for DATA BLOCKs for string variables. As the program is running, you will see that number go down into the low 2000s, as more and more memory has been consumed. Then the program will seem to stop for a few seconds. During this time, the computer is rearranging data in memory, to free up usable space. After this "housecleaning" is completed, the program will continue. You will then see that higher areas of memory are again being used.

Eventually, the program will get down into the 2000's again. The program will seem to stop again, while another housecleaning takes place. The program will resume, and again you will see that higher areas of memory are being used.

Several more times, you will see the computer get into the 2000's, do a housecleaning, and then resume in higher areas of memory. But as the program progresses, A$() accumulates more and more data. Housecleaning does less and less good. Memory is becoming overcrowded. Finally, you will get the OUT OF MEMORY message. The computer cannot find any more room for variable data.

CHAPTER 11
DISK STORAGE

In this chapter we will investigate how disk drives work. Even if you do not own a disk drive right now these chapters will probably be useful to you, for two reasons:

Most people today have disk drives, and the cost of disk drives continues to drop. So there is a good chance that you will use a disk drive (either the 1541 or the new 1571) with your COMMODORE-128,

Even if you never get a disk drive for your COMMODORE-128, the chances are very great that eventually you will use a some other computer which does have a disk drive. Most disk drives work in about the same way, regardless of computer. So the information that you obtain here will probably be useful later.

A disk drive is a lot like a cassette tape recorder. In fact, a disk drive and cassette recorder are so similar, that you can actually attach a cassette recorder to your computer and use it much like a disk drive.

A cassette recorder is a simpler mechanism than a disk drive. It is also more familiar to us than a disk drive. For this reason, we will begin by discussing how a cassette recorder works with a computer. Then we will turn our attention to disk drives.

In the back and on the side of your computer, there are a number of plugs. You can attach various devices to these plugs : printer, screen, modem, joystick, or cassette recorder. The computer can send and receive information from devices which are attached to these plugs.

If you plug a cassette recorder into your computer, the computer can send electronic signals out through the plug, and into the recorder. The recorder will then record each signal onto its tape. Each signal that is recorded on the tape is equal to one bit of information. For instance, if the computer wanted to store the word "WAX" in the cassette recorder, here is what would happen:

The computer would transmit 24 electronic signals to the cassette recorder:

0 1 0 1 0 1 1 1 0 1 0 0 0 0 0 1 0 1 0 1 1 0 0 0

The meaning of these signals is as follows:

! W !! A !! X !

0 1 0 1 0 1 1 1 0 1 0 0 0 0 0 1 0 1 0 1 1 0 0 0

The first 8 signals are ASCII for "W", the next 8 signals are ASCII for "A" and the last 8 are ASCII for "X".

These 24 signals are recorded on the tape in the cassette recorder. If you played the cassette back through a speaker, you would actually hear 24 sound impulses, the 1's have a certain kind of sound and the 0's have a certain kind of sound. (The overall sound effect is an uneven "rat-ta-tat".)

(In addition to these 24 signals, the computer might send some other signals as well. For instance, it might send some signals to turn the cassette motor on or off, or to mark the start or end of a stream of data.)

When you want to retrieve information from a cassette recorder and get it back into the computer, the reverse occurs:

The cassette recorder "reads" a portion of the tape and generates a stream of electronic signals. Each signal stands for a "1" bit or a "0" bit.

These signals go back into the computer.

And that is basically how a cassette recorder works with your computer.

Cassette recorders are simple and inexpensive. Unfortunately, they can be annoyingly slow and awkard to use. Suppose for example that you have a cassette tape with 20 programs on it, and you need the 18th program on the tape. In order to get at that program, you have to wind the tape all the way past the first 17 programs to get to it. If you then needed to get the first program off the tape, you would have to wind it all the way back to the beginning.

You do not have these problems with a disk drive. A disk drive uses the same basic storage concepts as a cassette recorder, but it is cleverly engineered to be much faster and convenient. The most important features of a disk drive are as follows:

1. A disk drive has a read/write head similar to what is in a cassette recorder. This read/write head is able to read or record electrical impulses on a magnetic oxide surface such as a cassette tape.

2. Instead of storing and reading information from a tape, a disk drive uses a disk. The surface of a disk is the same kind of material as on a tape. In fact, you can think of a disk as a short, fat tape, whose ends have been joined together.

3. Disk drives use a high-precision engineering that allow a large number of electronic signals to be stored in a compact area. This makes it possible to get at a desired piece of information more quickly than with a cassette recorder. No piece of information is very far away.

4. A disk drive rotates the disk at high speed. This enables any particular location on the disk to be accessed more quickly by the read-write head.

5. A disk is divided into "tracks" similar to the tracks on a recording tape. The tracks are numbered 0, 1, 2, ... Within each track are a number of "sectors" of 256 bytes each (Normally, the first two bytes of each sector are reserved for the computer's internal use, and cannot be used by you). Within each track, the sectors are numbered 0, 1, 2 . . .

6. On each disk there is a special area which maps out what information is stored in each sector. With the help of this map, the computer can locate information very quickly.

The technical details behind these concepts are quite complex. The reason for this complexity is

PERFORMANCE

By using advanced techniques for compacting information, organizing it, and mapping it, computer engineers have been able to make disk drives that are much faster and more convenient than cassette recorders.

Now let's find out what information looks like when it is stored on disk.

It is possible to store many different kinds of information on a single disk. On the same disk you can store programs, data files (such as a list of favorite baseball players, or a list of checks which you wrote last year), and text files (such as a letter to your uncle). In order to keep different kinds of information from getting scrambled together, the computer asks you for a file name each time you store information on a disk. On both the 1541 and 1571 you can have 144 separate files, the reason that the 1571 can't have more is that it still uses the same directory on track 18. Each file may be as short or as long as you like, up to the storage limits of the disk. The computer organizes all files on the disk so that they do not get tangled together.

We are going to create a simple example of a typical data file, and then we will find out what it looks like on disk. The name of the file will be CHAMPS, and it will hold a list of favorite baseball players. The file will hold the following information:

1 RUTH
2 MANTLE
3 KOUFAX

It is a list of three favorite baseball players, ranked from 1 to 3. Of course, this file could be much longer, but to keep the example simple, we will limit the file to 3 entries. Each entry then will consist of:

RANK (1-3) PLAYER'S NAME

The following program will create the file:

RUN THIS PROGRAM:

```
1 REM BASEBALL1
100 OPEN 2,8,2,"@:CHAMPS,S,W"
200 FOR I=1 TO 3
210 READ A$
220 PRINT#2,I;A$
230 NEXT I
300 CLOSE 2
400 DATA "RUTH","MANTLE","KOUFAX"
```

When you run the program, you will hear the disk drive whirr, while the file is being created. The program will create a file called CHAMPS which holds the rank and name of three baseball players.

HOW THE PROGRAM WORKS:

Line 100

```
100 OPEN 2,8,3,"@:CHAMPS,S,W"
```

tells the computer to start up a new file, whose name will be CHAMPS. The number 2 means that in the remainder of the program, we will refer CHAMPS as file number 2. The number 8 is the computer's shorthand for "disk drive". The number 8 tells the computer that we want to start this file on our disk drive, rather than, say, a cassette recorder. The number 3 has no special meaning, it is just required by the format of the command. The @ sign tells the computer that if there is already a file named CHAMPS on the disk, then replace it with this new file that we are about to create. The letter "S" at the end means that this is a "Sequential file" -- more about that later. The letter "W" means that we want to "Write" (record) information in the file.

Lines 200 - 230

```
200 FOR I = 1 TO 3
210 READ A$
220 PRINT#2,I;A$
230 NEXT I
```

store the three records in the file. The READ command tells the computer to READ an item off the DATA list in line 400

```
400 DATA "RUTH","MANTLE","KOUFAX"
```

and to store it in the variable A$.

Line 220

```
220 PRINT#2,I;A$
```

is the command that actually stores information in the file. PRINT#2 tells the computer to store data in file number 2 (which is CHAMPS). I;A$ are the data to be stored.

Line 300

```
300 CLOSE 2
```

tells the computer we are finished with file number 2 (which is CHAMPS).

Now let's see what the file CHAMPS looks like. To do this, we will write a program called BASEBALL2 which allows us to "peek" at individual bytes in a file. Unfortunately we cannot use the PEEK command to look into files, but there are other commands that allow use to get the same result.

ENTER THIS PROGRAM:

```
1 REM BASEBALL2
100 OPEN 2,8,2,"CHAMPS,S,R"
200 GET#2,A$
210 PRINT ASC(A$),A$
220 IF ST=0 THEN 200
300 CLOSE 2
```

RUN the program. The computer will display the data in CHAMPS, one byte at a time, in two columns. The left-hand column will show the ASCII code for each character. The right-hand column will display the character itself.

The information fills more than one screen. For your convenience, here is a complete display of what will appear on your screen:

```
32
49   1
32
82   R
85   U
84   T
72   H
13

32
50   2
32
77   M
65   A
78   N
84   T
76   L
69   E
13

32
51   3
32
75   K
79   O
85   U
70   F
65   A
88   X
13
```

Most of the codes are obvious in their meaning. We have highlighted those codes which are not.

The code

13

is used to separate each record from the next. There is a separator like this between

1 RUTH

and

2 MANTLE

and

    3 KOUFAX

Each record consists of a number and a name. The code

    32

is used to separate one from the other. 32 is the ASCII code for a space.

How does the computer know when the end of a file has been reached? It gets a signal from the disk drive. The disk drive is an "intelligent" device -- it contains a powerful "microprocessor" chip, and considerable RAM memory. It is able to sense when the end of a file has been reached. When it senses the end of a file, it sends a signal to the computer. This signal is stored in a special variable called ST (for "STatus"). Normally ST is 0. But when the end of a file is reached, ST is set to 64.

(How does the disk drive know when the end of a file has been reached? Well, at the end of the file is a special code which means "END OF FILE". When the disk drive senses that code, it sets ST to 64.

It would be interesting to take a look directly at the END OF FILE marker on the disk. Unfortunately, this requires advanced programming techniques which are beyond the scope of this book. If you want to learn the techniques, the subject you want to study is "random files". This subject is discussed in the Commodore disk drive manual. It is a tricky subject, because of some minor quirks in the design of the disk drive. You will have to familiarize yourself with some of these quirks before you can master the technique of working with "random files". However, once you have mastered the technique, you will be able to look at the exact contents of any sector on any track of a disk.)

Files can be used to store a wide variety of information, but the computer use the same basic methods for any kind of information.

The information is divided into units, and each unit is separated by the code 13 (or sometimes other codes such as 32)

When the end of a file is reached, the disk drive sends a signal to the computer, which shows up in the variable ST.

HOW BASEBALL2 WORKS

Line 100

```
100 OPEN 2,8,2,"CHAMPS,S,R"
```

tells the computer that we want to "read" information in the file CHAMPS. This command is similar to the OPEN command in BASEBALL1. The crucial difference is the "R" at the end of the command. This stands for "Read". This informs the computer that we only want to "read" information that is already in the file, we do not want to alter or erase any information.

Line 200

```
200 GET#2,A$
```

is used to "get" individual bytes from the file. Each time the command is executed, it gets one byte from the file, and stores it in the variable A$. The GET command retrieves bytes consecutively -- the first time it is executed, it gets the first byte in the file; the second time it is executed, it gets the second byte from the file; and so on. Each time, it gets the next byte after the last one it got. The computer automatically keeps track of where the GET command is in a file.

Line 210

```
210 PRINT ASC(A$), A$
```

prints the ASCII code for A$, and A$ itself.

Line 220

```
220 IF ST=0 THEN 200
```

checks the STatus variable, to see if the end of the file has been reached. If the end of file has not been reached, ST will be 0, and the computer will go back to the GET command in Line 200.

If the end of file has been reached, then ST will be set to 64. Once this has happened, the computer will go from line 220 to line 300

```
300 CLOSE 2
```

This command tells the computer that we are finished using file 2 (which is CHAMPS).

CHAPTER 12
DISK STORAGE PART 2

In the last chapter, we found out about the main concepts in the operation of your disk. We also saw how information looks when it is stored in a file.

In this chapter, we are going to find out about how the computer keeps track of where various information is on the disk. A floppy diskette on either the 1541 or the 1571 drive can hold up to 144 files, and a total of almost 175,000 bytes of data on the 1541 and almost 350,000 on the 1571. Yet when you need a piece of information from the disk, the computer can usually find the information almost instantly! How does it do that?

The answer is that on each disk, the computer maintains a pair of "maps", which shows where everything is on the disk. When you tell the computer to retrieve information from a file, the computer consults one of these maps to find out exactly where the file is located. The manner in which this is done is very complicated. We are going to survey just the main ideas that are involved, and then take a look at the "maps". They will not look like any maps you've seen before!

As you found out in the last chapter, each side of a diskette is divided into 35 tracks, and each track is divided into "sectors" or "blocks" of 256 bytes each. There are 17 to 21 sectors per track. There are 683 sectors altogether per side (Remember the 1571 is double sided for twice the storage).

Track 18 holds the two maps of the disk.

One of the maps is called the BLOCK AVAILABILITY MAP (BAM). The BAM shows exactly which sectors (blocks) on

the disk are used, and which are unused. Every time a file is added to the disk, every time a file is expanded, and every time old files are cleaned off the disk, the BAM is updated. BAM is 140 bytes long. For each sector on the disk, there is a bit in BAM which is assigned to that sector. If the sector is unused, the corresponding bit in BAM is set to 1. When the sector is used, the computer sets the corresponding bit in BAM to 0. By inspecting the BAM, the computer can tell exactly which sectors have been used, and which are unused.

The other map is called the DIRECTORY. The DIRECTORY is a list of files on disk, with some important information about each file. For each entry in the directory, the computer records the name of the file, the file type (Program file, Sequential file, User file, and Relative file), and the track and sector number where the file begins. When you tell the computer you want to use a file, the computer looks in the DIRECTORY to find out where the file begins on the disk. This saves the computer the trouble of searching through the entire disk to find the file you requested. This is why the computer can find files on your disk so quickly.

Once the computer finds the beginning of a file, it can find the remainder of the file quickly. This is because each sector in the file includes a 2-byte pointer, which tells the computer where the next sector of the file is located. The various sectors of a file may not be located side-by-side on the disk, but the pointers in each sector enable the computer to jump from one sector to the next quickly.

The precise layout of the BAM and the DIRECTORY is quite complex, and we will not discuss them in detail here. If you are interested in their exact layout, the details are covered in the Commodore disk drive manual.

The following program will allow you to take a look at both maps, so that you can get a sense for what they are like.

RUN THIS PROGRAM

```
1 REM MAPS
100 OPEN 2,8,2,"$,S,R"
200 GET#2,A$
210 IF A$ = "" THEN PRINT N,0: GOTO 230
220 PRINT N, ASC(A$)
```

```
230 N=N+1
240 C=C+1:IF C=20 THEN C=0:INPUT X$
250 IF ST=0 THEN 200
300 CLOSE 2
```

This program will display the contents of a file called "$". This is a special file, automatically set up by the computer when you initialize a diskette. This file contains the BAM and the DIRECTORY.

This program will display the contents of $ 20 bytes at a time. Each time you want to see 20 more bytes, press RETURN. Two columns of information will be displayed, the byte number, and the value of the byte in that location.

BAM will show up as bytes 2 - 141. You will notice that the pattern of byte values is irregular. This is because there are more sectors in some tracks than others, and because there are more bits in BAM than there are sectors on disk.

The DIRECTORY will begin at approximately byte 257. You will see ASCII codes for the names of files stored on the disk.

HOW MAPS WORKS:

The program is similar to BASEBALL2. The main difference is that it processes a file called "$", rather than CHAMPS. Also, the information from the file is handled a little differently.

Line 100

```
100 OPEN 2,8,2,"$,S,R"
```

tells the computer we want to "read" the file called "$". This is similar to the OPEN command in BASEBALL2.

Line 200

```
200 GET#2,A$
```

extracts one byte of information from the file. As we shall see, the variable N keeps track of how many bytes have been extracted.

Line 210

```
210 IF A$ = "" THEN PRINT N,0: GOTO 230
```

handles the situation of A$ having an ASCII code of 0. 0 means "null character", and it can set off error messages. Line 210 circumvents this problem.

Line 220 displays the value of N, and the ASCII code of A$

```
220 PRINT N, ASC(A$)
```

Lines 230 - 240 keep count of the number of characters processed. Every time C gets to 20, the screen display is frozen until RETURN is pressed.

```
230 N=N+1
240 C=C+1:IF C=20 THEN C=0:INPUT X$
```

Lines 250 and 300

```
250 IF ST=0 THEN 200
300 CLOSE 2
```

take care of finishing the program when the end of the file has been reached.

Now, a few concluding remarks on your disk drive.

The COMMODORE-128 disk drives are very complex devices. As was mentioned earlier, they are equipped with their own "microprocessor" and memory. Essentially, they have a small computer built right into them. It accepts several different sets of commands. Some of these commands are easy to learn (LOAD, SAVE), and others are intended only for advanced programmers. If you want to snoop further into the disk drive, here are some tips:

Study the user's manual which comes with the disk drive. The manual is stingy with examples and explanations, but you can extract almost everything you need to know by reading it closely.

Plan on writing a lot of experimental programs to familiarize yourself with the disk drive. Practice will fill in

the gaps left by the disk drive user's manual. Also, you will become acquainted with the quirks of the disk drive.

Bear in mind that there are four file types that are allowed by the disk drive. "Program files" are for programs. "Sequential files" are the simplest kind of data files. The file in the last chapter was a sequential file. "Relative files" are more advanced, and "User files" ("Random files") are the most advanced.

CHAPTER 13
SOUNDS

Earlier in this book, we experimented with the sound-making abilities of the COMMODORE-128. In this chapter, we will find out more about how your computer makes sounds.

As you already know, the COMMODORE-128 is a fabulous sound-making machine. It has many of the capabilities of a good electronic organ or sound synthesizer. It can imitate the the sounds of a piano, a clarinet, a guitar, and many other musical instruments. It can produce fabulous electronic arcade effects, and weird "outer space" sounds. The total range of sounds is so vast, that many possibilities have not yet even been explored. There are probably many kinds of sounds and musical effects still waiting to be discovered.

Sounds are made possible by a special device inside your computer called the "Sound Interface Device", or "SID" for short. SID is actually a tiny computer in its own right. It is a special purpose computer. Its sole job is to produce sounds. Here are the essentials of how it works:

SID is "tied in" to a certain region of memory, Locations 54272 - 55295. This region is reserved for SID.

The first 29 bytes of this region are reserved as a "message area" for SID. When the computer wants SID to do something, it leaves appropriate information in the message area. SID is constantly watching the message area. When a message comes in, SID does whatever the message says for it to do.

The remaining 995 bytes of the region are reserved as a "work area" for SID's use only.

SID does not actually produce sounds, only streams of electronic signals. When those signals are fed into a TV set or stereo system, they are then converted to sound.

You can control SID by POKEing information into the message area for SID, locations 54272 - 54300. When you POKE information into the message area, SID will "read" the message, and it will do whatever the message tells it to do.

Now, some bad news: SID is not a "friendly" device to communicate with. In order to communicate with it, you must POKE codes into the various positions in the message area. Each position has its own meaning, and contributes in its own way to the overall sound. The new sound commands built into the C-128 make this much easier but we will cover the basic principals first.

To thoroughly understand SID, you would have to understand the meaning of each position in the message area, and the way it responds to various POKEs and commands. Also, you would have to understand the ways the various positions contribute to the overall sound. This is sometimes difficult to predict, some combinations produce subtle and surprising effects. Even the best musicians are unable to predict all effects.

So, you cannot expect to understand everything about SID all at once. To help you get started, we will present a map which shows many of the features of the message area. Then we will write a program that will help you to experiment with various POKEs into the message area. This will acquaint you with many of the main features of SID. It will provide you a foundation for your own investigations of SID.

The following map will show you the main features of the message area (A few of the most advanced features are omitted). As you study this map, do not expect to understand everything the first time. We are trying to describe sounds with words, which is difficult. Later in the chapter, you will have a chance to experiment with SID, and discover with your own ears how it works.

Locations 54272 - 54278: Controls for voice 1. SID is able to produce 3 completely separate sounds at one time. Each of these sounds is known as a "voice". Each voice has its own set of controls. Voice 1 is controlled with the

information in locations 54272 - 54278. We will now explain the meaning of each of thoselocations.

Locations 54272 - 54273: Frequency (pitch). The values in this location determine the "pitch" of the sound -- how high or low it is. A high pitch is like a piccolo or the chirp of a bird. A low pitch is like a tuba, or the growl of a bear.

The pitch value is defined as

(VALUE OF BYTE 54272)+(256*VALUE OF BYTE 54273)

The higher this value, the higher the pitch.

Locations 54274 - 54275: Pulse waveform width. This is used to adjust the sound quality of "pulse waveform", described below.

Location 54276: Sound quality. Sounds can have various qualities -- they can be pure, mellow, buzzy, raspy, noisy, and so on. SID can produce 4 important basic sound qualities. All four of these qualities have precise technical characteristics which we will not discuss here. The four qualities are:

TRIANGLE WAVE: Mellow, flute-like

SAWTOOTH WAVE: Bright, brassy

PULSE WAVE: Can have a variety of qualities, some of them surprising. There are many kinds of pulse waves, varying from "thin" to "fat". This can be controlled in locations 54272 - 54275.

WHITE NOISE: Sounds like radio static

The following chart gives the POKEs for these four qualities:

QUALITY	START	STOP
TRIANGLE WAVE	17	16
SAWTOOTH WAVE	33	32
PULSE WAVE	65	64
WHITE NOISE	129	128

So for instance, if you wanted to make a sound with a pulse wave, you would start the sound by POKEing 65, and you would stop it by POKEing 64. This will be illustrated later in the chapter.

Locations 54277 - 54278: ADSR. The volume of a sound changes as you are listening to it. For instance, the sound of a bell begins with an intense ping, then the volume drops quickly to a lower level, it holds at nearly that level for a long time, and it dies away very slowly. The sound of a stick breaking begins more gradually, climaxes with an intense S N A P, and then disappears quickly. Many sounds get much of their distinctive character from the subtle ways in which their volume rises and falls.

Scientists measure the rise and fall of volume by means of 4 concepts:

ATTACK: How suddenly the sound begins

DECAY: How quickly the sound falls to a middle-range volume

SUSTAIN: The level of the mid-range volume

RELEASE: How slowly it dies away

Attack, Decay, Sustain, and Release are known as the "ADSR" for a sound or the "envelope" for the sound. The following is a sample
ADSR chart for a bell:

ATTACK, DECAY, SUSTAIN, and RELEASE each may have a value of 0 - 15. Here is how the values of locations 54277 and 54278 are set:

VALUE OF LOCATION 54272 = (16 * ATTACK) + (DECAY)

VALUE OF LOCATION 54273 = (16 * SUSTAIN) + (RELEASE)

You will have a chance to experiment with ADSR and ENVELOPE later in the chapter.

This completes the list of controls for Voice 1.

Locations 54279 - 54285: Voice 2. Similar to voice 1.

Locations 54286 - 54292: Voice 3. Similar to voice 1.

Locations 54293 - 54295: Filter. This is similar to the "Treble" and "Bass" tone controls on a stereo system.

Location 54296: Filter, volume. This location is used to control both the filter, and the overall volume of sound produced by SID. The filter control may have a value of 0 - 7. It works along with the "Treble" and "Bass" controls, to affect the proportion of "highs" and "lows" that you hear in a sound. The volume control regulates the overall volume of sound produced by SID. It may have a value of 0 - 15; 0 means total silence, 15 is the highest volume. Here is how the value of location 54296 is set:

VALUE OF LOCATION 54296 = (16 * FILTER) + (VOLUME)

Locations 54297 - 54298: Connections with other devices. It is possible to connect joysticks and other devices to SID. For instance, you could tie in a joystick so that whenever you move the joystick forward, SID makes a higher sound, and whenever you move the joystick backwards, SID makes a higher sound. It is possible to connect up to 2 devices to SID. The signals from these devices will show up in locations 54297 and 54298.

Location 54299 - 54300: Readouts on Voice 3. These two locations describe in mathematical terms what Voice 3 is doing. A clever programmer can "feed back" this information into other parts of the message area, and produce very complex effects.

The following chart summarizes the POKE values which are possible for various locations in the SID message area:

LOCATION	POSSIBLE SETTINGS	COMMENTS
54272	0 - 255	Locations 54272 - 54273
54273	0 - 255	Controlfrequency for Voice 1.

54274	0 - 255	Locations 54274 - 54275 control pulse waveform
54275	0 - 15	for Voice 1. Used only when wave has been selected.
54276	16, 17 32, 33 64, 65 128, 129	Selects sound for Voice 1. Options are: TRIANGLE WAVE, SAWTOOTH WAVE, PULSE WAVE and WHITE NOISE.
54277	0 - 255	Locations 54277-54278 select the ADSR("envelope") for Voice 1. Location 54277 selects Attack and Decay.
54278	0 - 255	Selects Sustain and Release for Voice 1.
54279 - 54285		Controls for Voice 2
54286 - 54292		Controls for Voice 3
54293	0 - 7	Locations 54293 - 54295 control the filter.
54294	0 - 255	
54295	0 - 255	
54296	0 - 255	Controls filter, overall volume for SID.
54297	0 - 255	Locations 54297-54298 allow joy sticks, game paddles,
54298	0 - 255	other devices to be tied in with SID.The signals received from these devices are registered here.
54299		Locations 54299-54300 gives readouts on what is
54300		occurring with Voice 3. This information is intend -ed for programmers who want to produce "feedback" effects with SID. You

To really understand the meaning of the various controls for SID, you need to experiment with the many combinations of POKEs that are possible with SID. To get you started, we are going to write a program which helps you to experiment with some of the settings for Voice 1 only. This will show you a great deal about what SID can do. And you can use the program as a basis for further experiments on your own.

ENTER THIS PROGRAM:

```
1 REM SOUNDLAB
100 POKE 54296,15
110 B=54272
200 LF=0:HF=250
210 LP=0:HP=15
220 QQ=16
230 A=0:D=1
240 S=0:R=9
300 T1=1:T2=500
600 AD= 16*A + D
610 SR= 16*S + R
700 POKE B,LF:POKE B+1,HF
710 POKE B+2,LP:POKE B+3,HP
720 POKE B+5,AD:POKE B+6,SR
800 POKE B+4,QQ+1
810 FOR Z=1 TO T1:NEXT Z
820 POKE B+4,QQ
830 FOR Z=1 TO T2:NEXT Z
900 GOTO 700
```

This program POKEs various settings into the message area for Voice 1. Run the program. You will hear a little bell ringing.

Let's take a look at how the program works. Then we will experiment with SID by modifying the program in various ways.

HOW SOUNDLAB WORKS:
SOUNDLAB is a "skeleton" program which POKEs values into the message area for Voice 1. The easiest way to explain what it does is to list the meanings of the variables in the program.

B : The beginning of the message area for SID

LF, HF: These set the frequency (pitch) of the sound.

LP, HP: If the sound quality is PULSE, LP and HP control the width of the pulse.

QQ: This sets the sound quality. The possible settings are:

16	TRIANGLE WAVE
32	SAWTOOTH WAVE
64	PULSE WAVE
128	WHITE NOISE

A,D, S,R These set Attack, Decay, Sustain, and Release

T1 When a sound is turned on, this controls how long it stays on.

T2 SOUNDLAB plays a note over and over. T2 controls how much time there is between notes.

Now, let's see find out what the program does.

Line 100

```
100 POKE 54296,15
```

sets the volume control to the highest possible setting, which is 15.

Lines 110 - 300

```
110 B=54272
200 LF=0:HF=250
210 LP=0:HP=15
220 QQ=16
230 A=0:D=1
240 S=0:R=9
300 T1=1:T2=500
```

set the variables listed above to appropriate values.

The next group of lines perform some calculations that are needed before information can be POKEd.

```
600 AD= 16*A + D
```

```
610 SR= 16*S + R
```

The next group of lines POKE information into appropriate locations.

```
700 POKE B,LF:POKE B+1,HF
710 POKE B+2,LP:POKE B+3,HP
720 POKE B+5,AD:POKE B+6,SR
800 POKE B+4,QQ+1
```

The next group of lines start and stop the tone.

```
800 POKE B+4,QQ+1
810 FOR Z=1 TO T1:NEXT Z
820 POKE B+4,QQ
830 FOR Z=1 TO T2:NEXT Z
```

Line 800 starts the tone. This is done by POKEing 1 more than the value of QQ into the appropriate location. Line 810 is a time delay loop. It determines how long the tone will sound, before it is turned off.

Line 820 turns off the sound. This is done by POKEing the QQ into the same location where QQ was. Line 830 is another time delay loop.

Line 900

```
900 GOTO 700
```

enables the program to repeat the tone again and again.

Now let's experiment with the program, to learn more about SID. First we will learn about frequencies.

Add the following line to the program:

```
840 HF = HF-10
```

This will decrease the frequency (pitch) of the sound, each time it is repeated. Run the program. You will hear the bell tone get lower and lower. When HF decreases below 0, you will get an error message.

Now let's find out about sound qualities. Change line 220 to

```
220 INPUT QQ
```

You now will be able to INPUT various numbers into QQ when the program starts. The allowable values are:

16 (SAWTOOTH)
32 (TRIANGLE)
64 (PULSE)
128 (WHITE NOISE)

Try INPUTing each of these values, and notice the different kinds of sounds produced. The value of 128 is especially interesting: It produces a horrendous "banging" sound.

Now let's play with Attack, Decay, Sustain, and Release. Change line 220 back to

```
220 QQ=16
```

Change line 200 to

```
200 LF=0:HF=100
```

This will lower the pitch of all sounds to a more convenient level.

Now, add the following line

```
245 INPUT A,D,S,R
```

This will allow you to INPUT values for Attack, Decay, Sustain, and Release.

Now, RUN the program, and try these values for A, D, S, and R:

A	D	S	R	Comments
0	1	0	9	Bell
0	1	0	0	Clink or blip
0	15	0	0	Short toot
15	15	0	0	Almost a tap
3	7	7	7	Plink

ADSR settings can produce colorful effects when used with

the WHITE NOISE waveform (QQ=128). Let's try a few examples.

Change line 220 to

220 QQ=128

This will tell SID to produce WHITE NOISE. Run the program, and then INPUT the following values:

A	D	S	R	Comments
0	1	0	9	Horrendous banging
15	1	1	1	Footstep
15	1	1	10	21 gun salute

Now, let's find out about pulse waveforms. Pulse waves can be "fat" or "thin". This can be controlled by varying the value of the variable HP.

Make the following changes in your program:

Remove line 245. This was the line the allowed you to INPUT various values for A, D, S, and R.

Change line 220 to

220 QQ=64

This tells SID to use the pulse waveform

Add this line

840 HP= HP - 1

This will gradually reduce HP from 15 to 0.

Now RUN the program. You will hear the quality of the sound change as HP is reduced from 15 to 0. When HP gets below 0, the program will stop with an error message.

Finally, you should experiment with the timing loops controlled by T1 and T2. By varying these loops, you can create very interesting "interference patterns" between sounds. To get acquainted with these effects, re-run any of the experiments in this chapter, but change line 300 to

```
300 T1=1:T2=1
```

or change it to

```
300 T1=100:T2=1
```

If you would like to find out more about SID, here are some suggestions:

Experiment some more with SOUNDLAB. This will help you to discover with your own ears how individual features of SID work. Then try

the new sound commands:

Before the new commands were added to the C-128, programming music and sound was a task that left most people daunted, unable to take advantage of it's many capabilities.

VOLume Command

VOL sets the volume for the SID and is followed by a number between 0 (off) and 15 (loud). Example:

```
VOL 12
```

TEMPO Command

Use this command to change the speed of your music. The C-128 will default to a TEMPO of 8, but you can use any integer value from 0 to 255. To speed up your sound you might try the following:

```
TEMPO 30
```

ENVELOPE Command

The C-128 has 10 envelopes to simulate different instruments which are selected by ENVELOPE N where N is a number between 0 and 9.

```
0    Piano
1    Accordion
2    Calliope
3    Drum
4    Flute
```

```
5     Guitar
6     Harpsicord
7     Organ
8     Trumpet
9     Xylophone
```

There are many optional parameters available to set attack (0-15), decay (0-15), sustain (0-15), release (0-15), waveform (0-4), and pulse (0-4095). By experimenting using these you can modify your sounds to suit your needs or likings.

PLAY Command

This statement can be a lot of fun, now anyone can make music the first time they try. To start programming music just type:

```
PLAY "cdefgab"
```

or you can specify a string like

```
C$="BAGFEDC"
PLAY C$
```

Sharps and flats are very easy just put either a # (number sign) for sharp or a $ (dollar sign) for a shrp just before the note. The kind of note you wnat to play is selected by prececing your note by W for whole note, H for a half, Q plays a quarter note, I for an eighth note, S is a sixteenth and any of these can be dotted (.) to add one half to their values.

There are seven full octaves that you can use, the default octave is 4 but can be changed by the O command followed by a number between 0 and 6. Choosing which voice is just as simple: V1, V2 or V3. Try this example to listen to all the octaves (0 through 6) available but with no sharps or flats, note that we are able to build a string using the same notes and changing octaves:

```
100 VOL 10: TEMPO 20
110 C$="CDEFGAB"
120 B$="O0"+C$+"O1"+C$+"O2"+C$+"O3"+C$+"O4"
+C$+"O5"+C$+"O6"+C$
130 PLAY B$
```

You will have lots of fun with this command since it uses letters. Try using sentences and see what you can come up with. Use any letters but J, K, L, N, P, Y and Z. Listen to this:

```
TEMPO 30
PLAY "WE MAKE MUSIC"
```

SOUND Command

This command is for you if you want sound effects for your programs. The format is:

SOUND V,F,L, D,M,S,W,P

The first three parameters are the most important

V will set which voice 1,2 or 3

F frequency (0-65535)

L selects how ling a note will play
(1/60ths of a second)

The last five parameters are optional and are as follows

D direction of frequency "sweep
- 0 upward
- 1 downward
- 2 oscillate

M will set the minimum frequency (0-65535) if the D parameter is used

S sets the size of the steps for the "sweep" (0-32767)

W chooses the waveform
- 0 triangle
- 1 sawtooth
- 2 pulse
- 3 white noise

P selects the width of the pulse waveform

The COMMODORE-128 SYSTEM GUIDE has some

excellent examples of these commands but it is much more fun to come up with your own.

After you are familiar with the individual features of SID, you need to find out how to combine features and produce interesting musical effects. A good place to start is the COMMODORE-128 SYSTEM GUIDE, which has some nice examples of sound programs.

For a detailed understanding of SID, see the COMMODORE-128 PROGRAMMER'S REFERENCE GUIDE. This is hard reading, so don't expect to understand everything the first time!

To become really creative with SID, find out about the subject of "acoustics". Acoustics is the science of sound. It will help you to understand the "nuts and bolts" of sound effects and musical qualities, and will stimulate your own creativity.

CHAPTER 14
INTRODUCTION TO NEW COMMODORE-128 GRAPHIC COMMANDS

The C-128 has several high level GRAPHIC commands. These commands automatically take care of memory allocation that had to be done with numerous POKEs on the C-64. We will first explain and illustrate how to use these commands.

SCREEN LAYOUT : Lo-res, hi-res and bit-mapped

Lo-res (low resolution) graphics which are created in the text mode are all the designs that are visible on the front of the keys (e.g. hearts, spades & checkerboard) these can be used to achieve very elaborate effects. With these you can outline sections of your screens, draw simple figures and set up graphs.

Hi-res (high resolution) graphics allow single or multiple pixel placement of graphics . Using the new high-level BASIC Statements to access individual pixels, you can attain much more detail than in the text mode.

COLOR

Choose your border and background COLORs with the COLOR Command.
For instance:

COLOR 0,3

turns your background red. The first value selects which area and in which mode will be changed. The second number chooses the COLOR .

MODE SELECTION

Value	Explanation
0	40 column background
1	Foreground for graphics
2	Foreground 1 multiCOLOR
3	Foreground 2 multiCOLOR
4	40 column border
5	Character for 40 or 80 column
6	80 column background

COLOR CODES

IN 40 COLUMN MODES

CODE	COLOR	CODE	COLOR
1	Black	9	Orange
2	White	10	Brown
3	Red	11	Light Red
4	Cyan	12	Dark Gray
5	Purple	13	Medium Gray
6	Green	14	Light Green
7	Blue	15	Light Blue
8	Yellow	16	Light Gray

IN 80 COLUMN MODES

1	Black	9	Dark Purple
2	White	10	Dark Yellow
3	Dark Red	11	Light Red
4	Light Cyan	12	Dark Cyan
5	Light Purple	13	Medium Gray
6	Dark Green	14	Light Green
7	Dark Blue	15	Light Blue
8	Light Yellow	16	Light Gray

REGISTERS

The C-128 uses memory locations 53281 for the background COLOR and 53280 for the border, as does the C-

64. However the character COLOR control memory in the C-128 is at 55296. These values are memory locations and can be used to POKE the colors to the COLOR Memory Map in addition to the COLOR Command.

EXAMPLE:

```
10 GRAPHIC 1,1
20 COLOR 0,8:     REM BACKGROUND YELLOW
```

OR

```
10 POKE 53281,8: REM BACKGROUND RED
```

6 GRAPHIC modes

There are six ways to configure the C-128 for graphics . You can select which mode with the GRAPHIC Command followed by the proper values.

VALUE	Explanation
0	40 column text
1	hi-res bit-mapped
2	hi-res split screen
3	multi bit-mapped
4	multi split screen
5	80 column text

EXAMPLE:
GRAPHIC 1,1: REM HI-RES MODE AND CLEAR BIT-MAP

There are two other optional parameters for the GRAPHIC Command.
First there is an option to clear the bit mapped (hi-res) screen. A value of 1 will clear the screen and 0 will leave the graphics on the screen.
The third option is for sets the text area in a split screen mode (either 2 or 4). If no parameter is set the split defaults to lines 20-25 in text mode and the rest of the screen is bit mapped. Set the starting line of the text portion of the screen from 1 to 25. Setting a zero value creates an all bit-mapped screen.

The final GRAPHIC Command option is 'GRAPHIC CLR'. It is used alone without any other GRAPHIC parameters. CLR is used to clear the memory (9K) that you may have allocated for bit-mapped graphics .

EXAMPLES:

GRAPHIC 0,1 :REM TEXT MODE AND CLEAR BIT-MAP

GRAPHIC 3,0 :REM MULTI-COLOR MODE NOT ERASING BIT-MAP

You should remember to use the GRAPHIC CLR Command when you are finished with your hi-res screens because the amount of memory allocated is substantial.

The bit-mapped screen (in all modes but text) uses 8000 bytes of memory. In hi-res mode an additional 1000 bytes are needed for the background and foreground data. Multi-COLOR data requires 2000 bytes and in split screen modes these are in addition to the normal allocation for text.

PLOTTING & DRAWING

x - y Coordinates of screen

Think of your screen as a grid with x (319) columns and y (199) rows and they both originate from the top left corner of your screen (0,0).

New graphics Commands

The pixel coordinates can be either absolute (160,100) or relative to the previous pixel position. For example: +15,+20 moves the pixel cursor 15 pixels to the right and up 20 pixels. This will save you considerable time instead of replotting every point on the screen each time.

The X and Y Coordinates can be either absolute or relative to the previous pixel position.

```
   x,    y     Absolute x, Absolute y
+/-x,    y     Relative x, Absolute y
   x, +/-y     Absolute x, Relative y
+/-x, +/-y     Relative x, Relative y
```

Be careful using the parameters because even if you do not need them (they will be set to default) their place must be held by a comma .

One major thing to watch out for in each of the following commands is scaling because the x and y axis are not equal (320/200). Just use 2/3 of the x value for the y value for a rule of thumb, since that is easier to remember than 5/8 or 0.625.

CIRCLE

This command allows you to plot circles, ovals, arcs and even octagons.

CIRCLE COLOR ,X,Y,Xrad,Yrad,ba,ea,Rot,inc

Where COLOR is

```
0  Background
1  Foreground
2  MultiCOLOR  1
3  MultiCOLOR  2
```

```
X,Y      Center of the CIRCLE
Xrad     X radius
Yrad     Y radius (default is Xrad)
ba       Beginning angle
         (default is 0 degrees)
ea       Ending angle (default
         is 360 degrees)
Rot      Rotation degrees clockwise
         (and default is 0 degrees)
```

```
Inc          Increment between segments
             (default is 2 degrees)
```

Setting a large Increment will allow you to draw Octagons (increment of 45) or other angular shapes. Try the examples below then change the parameters for various effects.

EXAMPLES :

```
10 COLOR 0,7      : REM SET BACKGROUND TO BLUE
20 COLOR 1,3      : REM SET FOREGROUND TO RED
30 GRAPHIC 1,1 : REM HI-RES, CLEAR BIT-MAPPED
40 CIRCLE1,160,100,60,40 : REM DRAW A CIRCLE
50 CIRCLE1,+30,100,30,20 : REM A SMALLER INSIDE
60 CIRCLE1,65,100,60,45,,,,45 : REM OCTAGON
```

(COMMAS HOLD DEFAULT PARAMETERS)

DRAW

The draw command will let you draw accuratly and place your design anywhere on the screen. Try a few drawings to get a feel for using the coordinates.

DRAW COLOR ,X1,Y1 TO X2,Y2

```
Where COLOR  0  Background
             1  Foreground
             2  MultiCOLOR  1
             3  MultiCOLOR  2
  X1,Y1     Starting point (coordinates 0,0
            to 320,200)
  X2,Y2     Ending point (0,0 to 320,200)
```

EXAMPLE:

```
10 COLOR 0,8       :REM BACKGROUND TO YELLOW
20 COLOR 1,6       :REM FOREGROUND TO GREEN
30 GRAPHIC 1,1  :REM HI-RES, CLEAR BIT-MAP
50 DRAW,160,100TO220,199
60 DRAW,220,199TO100,199 :REM DRAW TRIANGLE
70 DRAW,100,199TO160,100
80 DRAW,0,0TO320,200
90 DRAW,0,25TO320,175  :REM DRAW DIAGONAL
```

95 DRAW,0,50TO320,150

BOX

Using this command instead of DRAW will save you some typing if you want to draw or enclose something in a box.

BOX COLOR ,X1,Y1,X2,Y2,Rot,Paint

```
Where COLOR  0  Background
             1  Foreground
             2  MultiCOLOR  1
             3  MultiCOLOR  2
   X1,Y1     Top left corner (scaled)
   X2,Y2     Bottom right corner) default
             is the pixel cursor location)
   Rot       Rotation in degrees (clockwise
             and default is 0 degrees)
   Paint     Fills shape with COLOR
             (default is 0)
                0  Do not paint
                1  Paint
```

Examples:

```
10 GRAPHIC 3              :REM SET MULTI-COLOR MODE
                               AND CLEAR BIT-MAP
20 BOX3,20,20,50,50       :REM DRAW A BOX WITH
                               MULTI-COLOR 1
30 BOX2,55,55,70,70       :REM DRAW A BOX WITH
                               MULTI-COLOR 2
40 BOX3,80,80,140,140,45,1 :REM DRAW A BOX
                               THEN ROTATE AND FILL
```

CHAR COMMAND

On a hi-res screen you must use the CHAR Command to put words on the screen just as you use the PRINT Statement in text mode.

CHAR COLOR ,X,Y,String,RVS

```
Where COLOR  0  Background
             1  Foreground
             2  MultiCOLOR  1
```

```
          3  MultiCOLOR  2

X         Beginning column (0-79)
          (In 40 column mode this wraps
          around to the next line)
Y         Beginning row (0-24)
String    String to print
RVS       Reverse Field (default 0 off)
             0  Off
             1  On
```

This example incorporates all the previous GRAPHIC Commands. Try using some of these techniques like random numbers and looping in your own GRAPHIC programs.

EXAMPLE:

```
10 GRAPHIC 1,1 : REM BIT-MAP MODE AND CLEAR
20 COLOR 1,8 : REM FOREGROUND TO YELLOW
30 COLOR 0,7 : REM BACKGROUND TO DK. BLUE
40 CIRCLE1,150,100,60,40,270,90
50 DRAW,0,100TO350,100 :REM DRAW LINE ACROSS
60 PAINT1,148,90 :REM FILL HALF CIRCLE
70 DRAW,85,75TO90,75
80 DRAW,90,75TO95,72
90 REM LOOP TO PRINT RANDOM 'SEAGULLS'
100 FOR I=1 TO 30
110 REM RANDOM NUMBERS FOR TOP OF SCREEN
120 C=INT(RND(1)*320):D=INT(RND(1)*97)
130 DRAW,C,DTO+5,D :REM DRAW WITH RELATIVE
                        PIXEL CURSOR
140 DRAW,C,DTO+5,+3
150 NEXT I
160 REM CHAR COMMAND TO THE SCREEN
170 CHAR1,9,20,"PRESS ANY KEY TO EXIT",1
180 GETA$:IFA$=""THEN180 :REM GET KEYPRESS
190 GRAPHIC 0,1:LIST :REM CHANGE BACK TO
                     TEXT MODE AND LIST
```

'**SCALE**'ing your graphics

You may find it easier to have smaller increments when designing graphics . This command alows you to SCALE both the x and y coordinates from 0 to 32767. Instead of:

BIT-MAPPED MODE X = 0 to 319 Y = 0 to 199
MULTI-COLOR MODE X = 0 to 159 Y = 0 to 199

SCALE M,Xmax,Ymax

```
Where M          0  Off
                 1  On
  Xmax,Ymax      Regular bit-mapped mode
                 (Default is 1023)
                 320<= Xmax <32767
                 200<= Ymax <32767
  Xmax,Ymax      Multi-COLOR  mode
                 (Default is 511)
                 160<= Xmax <32767
                 160<= Ymax <32767
```

EXAMPLES:

```
10 GRAPHIC 1,1 :REM BIT-MAP MODE
20 SCALE1      :REM DEFAULT SCALING (1023,1023)
30 CIRCLE1,550,300,300,300  :REM DRAW A CIRCLE
```

```
10 GRAPHIC 3,1 :REM MULTI-COLOR MODE
20 SCALE1,5000,3000 :REM SCALING TO 5000,3000
30 CIRCLE1,550,300,300,300  :REM DRAW A CIRCLE
```

SPRITES

Sprites are a way to get graphics and movement, by moving a "block" of pixels instead of individual re-plotting of all the points. You can creat Sprites with the DRAW Command or the sprite statements from in a program or in the SPR ite DEF ination mode.

You can have eight different sprites at the same time, choose, move them independantly of one another and leave you bit map screen untouched. Sprites can be DATA statements or binary files or string variables.

The COMMODORE 128 SYSTEM GUIDE has a very good step by step tutorial on the creating, storing and moving sprites.

Sprite definition is with the SPRDEF routine which is located at locations $0E00-$1000. Also look at locations 12FA through 12FC which are used by SPRDEF.

PEN COMMANDS

Reading the PEN locations are easier on a light background so set your color to white for the best results. Printing coordinates on either a 40 or 80 column screen and detecting if the trigger has been activated.

PEN (n)

where n is

```
0   X position 40 column mode
1   Y position 40 column mode
2   X in 80 column mode
3   Y in 80 column mode
4   gives the trigger value
```

Drawing with a Light-Pen

```
110 PRINT  CHR$(147)
120 COLOR 0,2
130 COLOR 1,3
140 GRAPHIC  1,1
150 DO UNTIL PEN(4): LOOP
160 X=PEN(0):Y=PEN(1)
170 IF Y>50 THEN Y=Y-50
180 IF X>50 THEN X=X-50
190 DRAW 1,X,Y
200 GOTO 160
```

WINDOWING

It is easy to set the parameters for this command select the top left and the lower right hand corners. There are two ways to do this with WINDOW Command or ith ESC Key sequence.

WINDOW X,Y, X2,Y2

The first X and Y are the top left position and X2 and Y2 are the lower right . Be careful of which mode you are in either 40 or 80 columns. Your cursor and your commands will be

shown and executed in the window.

The second way is even easier. Place your cursor where you want the top right corner press ESC then T (for top) move the cursor to the lower left corner you want and again press ESC the B. Try this:

Place your cursor half way down the left side of your screen and press the

ESC then the **T** keys

move the cursor to the right and down to the bottom of the screen. Press

ESC and **B**

Now type **KEY** and the definitions will list in the window! So try using Windows in your programs to show a listing in one corner. Try looking at locations C02D and CA07 with the SNOOP program to see where the routine for window definition is.

Programmers use graphics to achieve the desired screen or printed appearance of their work. But everyone at some point will need to use some graphics on their computer and until now that could be daunting. The new GRAPHIC commands that we have covered here will make designing and displaying your graphics easy.

CHAPTER 15
MACHINE LANGUAGE

Several times we have mentioned **6502 Machine Language.** All of the routines of the KERNAL are written in this language. Also, when you are running a program in BASIC, the computer actually translates each command into 6502 machine language before executing it. The computer does this because, machine language is the "native language" of the computer. The computer cannot perform any task unless it has been expressed in the commands of machine language.

In this chapter we will find out what machine language programs are like.

Machine language consists of the simplest, most fundamental commands that can be given to a computer. Here are some sample commands:

Transfer a byte of information from one storage location to another.

Add two numbers.

Multiply two numbers.

Compare two values; if they are the same, set a certain storage location to "1"; otherwise set it to 0.

Compare the individual bits in two different bytes; whenever the bits don't match, set the appropriate bit in the first byte to "0".

Go to a certain place in the machine language program, if a certain value is zero.

Many of the commands that you enjoy in BASIC do not have counterparts in machine language. For instance, in machine language you do not have counterparts for any of these commands:

```
PRINT
X$ = "EVERYTHING IS FINE"
SAVE
INPUT
IF ... THEN
FOR ... NEXT
```

It is possible to use a group of machine language instructions that will accomplish the same results as any of these BASIC commands, but it is tedious work. For instance a machine language program to do the same job as this command

```
SAVE "SNOOP",8
```

would require hundreds of instructions!

Why would anyone use machine language? There are three main reasons:

The COMMODORE-128 is constructed from certain fundamental components which only understand machine language. So the engineers who developed the COMMODORE-128 had no choice but to dosome of the initial programming in machine language.

Machine language programs run much faster than BASIC programs, often 10 to 100 times faster.

You can do things in machine language which are impossible in BASIC. For instance, many communications programs must be written in machine language in order to work reliably (Communications programs often require data to be transmitted and received at precise speeds. BASIC programs execute at slightly "uneven" speeds, and this makes BASIC unsuitable for some communications programs. In machine language, the execution speeds can be controlled precisely.)

Here is what a machine language program looks like:

```
101000000000000010101001001000001001100100000000
0000100100110010000000000000010110011001000000000
0001101001100100000000000001111100100011010000111
1000110100000000000001010100100000111100110010000
0000000001001100100010101001000011111001100100000
0000000010011001000101010010001001110011001000000
0000000100110010001010100100001000100110010000000
000000100110010001010000000000000010101001000000001
1001100100000000110110001100100010011001000000001
1011000110010001001100100000000110110001100100010
011001000000000110110000110000
```

Each 1 or 0 is one bit in the program. The job of this particular program is to clear the screen, and then display the word 'GOSH' in the upper left-hand corner. We are going to analyze this program piece by piece to see how it works. Our aim in doing this is not really to learn machine language -- that would require an entire book in itself. Instead, we just want to get a sense for what the language is like. This will give us insight into how the computer really "thinks".

The program consists of 31 commands. There is no punctuation in the program to indicate where one command ends and the next one begins. The computer figures out the beginning and end of each command from context. For instance, the program begins with the following eight bits:

10100000

From this the computer knows that the first command is an LDY-Immediate command, which is two bytes (16 bits) in length. So it knows that the second command begins with the 17th bit in the program. When it examines the second command, it will figure out how many bits long that command is, and then it will know where the third command begins. And so on. To make the program easier to read, we are going to break it up into the 31 commands of which it is composed.

```
[ 1 ]     1010000000000000
[ 2 ]     1010100100100000
[ 3 ]     100110010000000000000100
[ 4 ]     100110010000000000000101
[ 5 ]     100110010000000000000110
[ 6 ]     100110010000000000000111
[ 7 ]     11001000
[ 8 ]     1101000011110001
```

```
[ 9 ]     1010000000000000
[ 10 ]    1010100100000111
[ 11 ]    100110010000000000000100
[ 12 ]    11001000
[ 13 ]    1010100100001111
[ 14 ]    100110010000000000000100
[ 15 ]    11001000
[ 16 ]    1010100100010011
[ 17 ]    100110010000000000000100
[ 18 ]    11001000
[ 19 ]    1010100100001000
[ 20 ]    100110010000000000000100
[ 21 ]    11001000
[ 22 ]    1010000000000000
[ 23 ]    1010100100000001
[ 24 ]    100110010000000011011000
[ 25 ]    11001000
[ 26 ]    100110010000000011011000
[ 27 ]    11001000
[ 28 ]    100110010000000011011000
[ 29 ]    11001000
[ 30 ]    100110010000000011011000
[ 31 ]    01100000
```

We have numbered these commands from [1] to [31]. Now let's look at some of these commands individually. (If you are not interested in all of the technical detail, it's okay to just skim through this discussion.)

Command [1]

1010000000000000

is known as an LDY-Immediate command. It tells the computer to "load" 8 bits into a storage location known as "register Y". Here is how to read the command:

The first eight bits

10100000

mean that this is an LDY-Immediate command.

The next 8 bits

00000000

are the bits to be moved into Register Y.

So, in summary, the command says to move the following 8 bits

00000000

into register Y.

A **register** is a special kind of memory that is used for tasks that must be performed at the highest possilbe speed. Register-memory is engineered in a different way than regular memory. It is expensive, and it operates at a higher speed than ordinary memory. A register holds either 8 bits or 16 bits. There are just 7 registers altogether. Registers cannot be accessed from BASIC. PEEK and POKE commands cannot address registers.

Most machine-language operations require that the data involved be moved into registers to be operated upon. So for instance, if you want to add two numbers, one of the numbers must first be placed in a register, and the result of the addition is left in a register. This entails a lot of shuffling around of information inside the computer. However engineers have found this to be a very efficient way of designing computers overall, the advantages outweigh the inconveniences.

Command [2]

1010100100100000

is known as an LDA-Immediate command. This is similar to the previous command. It tells us to load 8 bits into a storage location known as "register A". Here is how to read the command:

The first eight bits

10101001

mean that this is an LDA-Immediate command.

The next 8 bits

00100000

are the bits to be moved into register A.

So the command says to move the following 8 bits

00100000

into Register A.

Command [3]

100110010000000000000100

is known as a "STA-Absolute,Y" command. This is similar to a POKE command. It stores the contents of Register A into a certain location in memory. Here is how it works:

The first 8 bits

10011001

tell the computer that this is a STA-Absolute,Y command.

The remaining 16 bits

0000000000000100

are used by the computer to determine the location where the contents of Register A will be stored. To determine that location, the computer calculates a value based on those 16 bits, and then adds the value currently in Register Y. (We will omit the mathematical details involved here.)

In summary, STA-Abolute, Y is like a POKE command. In this case, the command does the same work as the following POKE comand

POKE 1024,32

Commands [4], [5], and [6] are also STA-Absolute,Y commands. Notice that they all begin with the eight bits

10011001

This tells the computer that they are STA-Absolute,Y commands. All machine language commands are identified by the first eight bits.

We will come back and find out more about commands [4], [5], and [6] later. Right now, let's look at a few other commands in the program.

Command [7]

11001000

is known as an INY command. This command tells the computer to "increment" the value of register Y by 1. For example

OLD VALUE IN REGISTER Y	NEW VALUE IN REGISTER Y
00000000	00000001
00000001	00000010
00000010	00000011
11111110	11111111

If the old value in register Y is 11111111, INY will change it to 00000000. I.e.

OLD VALUE IN REGISTER Y	NEW VALUE IN REGISTER Y
11111111	00000000

Command [8]

1101000011110001

is known as a BNE command. This tells the computer that if the value in Register Y is not equal to 00000000, then back up 15 bytes in the program. This takes the computer back to Command[3]. BNE is kind of a special version of an IF ... THEN command in BASIC. BNE says that if a certain value is not 00000000, then goto a certain location in the program. Here is how to read the command:

The first eight bits

11010000

tell the computer that this is a BNE command.

The next eight bits

11110001

tell the computer how far to back up in the program, if the value of register Y is not 00000000. (We will omit the mathematical details here.)

Command [31]

01100000

is known as an RTS command. This tells the computer that the program is done, and to return to whatever the computer was previously doing before this program began.

You have now seen all the different kinds of commands that go into the program. The entire program is just a combination of LDY, LDA, STA, INY, BNE, and RTS commands. Let's review what these commands do:

LDY and LDA load information into registers.

STA stores some information from a register into a location in memory.

INY increments that value in a certain register.

BNE tells the computer to go back to an earlier instruction,

if the value in a certain register is not 00000000.

RTS finishes the program.

All of these commands perform very simple tasks. The entire program consists of loading information into registers, transferring information from registers to certain locations in memory, incrementing values in registers, and a sort of IF ... THEN loop. Since the individual commands are so simple, couldn't you write a program in BASIC that would do the

same work? The answer is Yes. Here is a program in BASIC which is almost identical, line for line:

```
MACHINE LANGUAGE                            BASIC
--------------------                        --------------

[ 1 ]  1010000000000000                     1  Y=0
[ 2 ]  1010100100100000                     2  A=32
[ 3 ]  100110010000000000000100             3 POKE 1024+Y,A
[ 4 ]  100110010000000000000101             4 POKE 1280+Y,A
[ 5 ]  100110010000000000000110             5 POKE 1536+Y,A
[ 6 ]  100110010000000000000111             6 POKE 1792+Y,A
[ 7 ]  11001000                             7 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 8 ]  1101000011110001                     8 IF Y<>0 THEN 3
[ 9 ]  1010000000000000                     9 Y=0
[ 10 ] 1010100100000111                    10 A=7
[ 11 ] 100110010000000000000100            11 POKE 1024+Y,A
[ 12 ] 11001000                            12 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 13 ] 1010100100001111                    13 A=15
[ 14 ] 100110010000000000000100            14 POKE 1024+Y,A
[ 15 ] 11001000                            15 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 16 ] 1010100100010011                    16 A=19
[ 17 ] 100110010000000000000100            17 POKE 1024+Y,A
[ 18 ] 11001000                            18 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 19 ] 1010100100001000                    19 A=8
[ 20 ] 100110010000000000000100            20 POKE 1024+Y,A
[ 21 ] 11001000                            21 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 22 ] 1010000000000000                    22 Y=0
[ 23 ] 1010100100000001                    23 A=1
[ 24 ] 100110010000000011011000            24 POKE55296+Y,A
[ 25 ] 11001000                            25 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 26 ] 100110010000000011011000            26 POKE 55296+Y,A
[ 27 ] 11001000                            27 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 28 ] 100110010000000011011000            28 POKE 55296+Y,A
[ 29 ] 11001000                            29 Y=Y+1:IF Y=256
                                              THEN Y=0
[ 30 ] 100110010000000011011000            30 POKE 55296+Y,A
[ 31 ] 01100000                            31 END
```

As you read through the BASIC version, think of the variable Y as standing for Register Y, and think of the variable A as standing for Register A.

Now that we have seen in detail what machine language is like, let's summarize some important points about it.

Machine language is frustrating to read. The lack of punctuation and the exclusive use of 1's and 0's are especially troublesome.

The individual commands perform very simple tasts. It is fairly easy to understand what each individual command does. The only real difficulty there is understanding the details of how various numbers are expressed (i.e. how the bits 0000000000000100 stand for location 1024 in memory). We have not discussed those difficulties in detail, but they are fairly easy to master.

It takes a lot of commands to perform even a simple task. In our sample program, it took 7 commands just to clear the screen.

Machine language is really the only language that the computer can understand. If you give it a command in BASIC, the computer will translate the command into a series of machine language commands, before executing your original command.

Your computer can process machine language commands very quickly, often 10 to 100 times faster than equivalent programs in BASIC. Machine language is awkward for human beings, but easy for the computer.

You can do things with machine language that cannot be done at all with BASIC.

Memory is filled with hundreds of machine language routines to perform various fundamental tasks. Although any single routine performs a small task, the computer system can build more complex routines from simpler ones.

If you were to analyze how the computer performs a complex task, you would see that it usually breaks it down into a series of simpler tasks. For instance, consider the task of displaying a program on the screen, when you enter the command LIST.

This requires the computer to trace through the entire program, line by line, code by code, and to translate each code into the appropriate code for displaying on the screen. It requires deciding when to begin a new line of display on the screen. It also requires the ability to handle special situations (What to do if the program is too big to fit on the screen, what to do if a code is encountered in the program which does not make any sense). The computer carries out this job by breaking it down into some simpler tasks. Here are some of the simpler tasks:

Find the next byte of the program in memory.

Translate a byte from the program into one or more characters that can be displayed on the screen.

Display a certain character at a certain position on the screen.

Check to see if a certain position on the screen is the last position on the screen.

(If the screen is filled,) scroll the screen up one line.

Advance to the next unused position on the screen.

These are not all of the tasks required for LISTing a program. Some important tasks have not been mentioned at all. Also, some of the tasks shown above can be broken down into a set of still simpler tasks. But this example makes it clear that if a computer knows how to perform a large number of simple tasks, it will then be able to combine these tasks to accomplish more significant work.

THE THIRD RULE OF COMPUTER SNOOPING: *Your computer system is built up in layers.*

The way the COMMODORE-128 was created was to start with some electrical components that can perform various simple commands. These components were assembled in the same "box". Machine language programs were then developed to "teach" the computer to perform a large number of simple but important tasks. Once this was accomplished, the next step was to develop some additional machine language programs that combine the simpler programs, in

order to accomplish more complex tasks. Here are some examples of what is found in each layer:

LOWEST LAYER: Machine language commands such as LDY-Immediate, LDA-Immediate, STA-Absolute,Y, INY, BNE, and RTS

NEXT LAYER: Simple machine laguage routines such as

A machine language routine to clear the screen

A machine language routine to display the word READY on the screen

A machine language routine to make the cursor flash at the proper speed

HIGHER LAYERS: Machine language routines that combine simpler routines to perform more complex tasks, for instance

A routine to display the appropriate symbols on the screen, in the right places, as you are typing

A routine to restore the computer back to normal when you press STOP-RESTORE

EVEN HIGHER LAYERS: Machine language routines which translate your BASIC commands into machine language routines.

CHAPTER 16
C-128 HARDWARE

In each chapter of the book so far, we have investigated some important aspect of your COMMODORE-128. We have found out about the screen, various parts of memory, programs, variables, sound, and machine language.

In this chapter we will take a different approach. Instead of concentrating on just one aspect, we will take an overview of the entire computer system. To do this, we will survey all of the main components of the COMMODORE-128, and discuss how they work together.

The main parts of the COMMODORE-128 are

An "8500 Microprocessor". This is the device that does most of the thinking for the computer. It processes all machine language commands. It organizes and controls almost all activities of the computer.

Memory. As we have seen, memory is used for many purposes. It holds reference information and machine language programs. It is used to track most of the activities that go inside the computer. Parts of it are reserved for use as a scratch pad.

Add-ons (Peripherals). This includes all the devices that can be attached to the COMMODORE-128 to make it more convenient and useful for you. Examples are: Screen, printer, disk drive, modem, and joystick.

Communications lines. These lines enable the different parts of the PC to send information to each other and to work together.

Special-purpose devices. The COMMODORE-128 is equipped with several devices which specialize in certain kinds of tasks. One example is SID, which specializes in making sound and music. Another example is the VIC II microprocessor, which specializes in screen displays.

Let's find out about each of these parts in more detail.

The 8500 microprocessor does most of the "thinking" for the computer. It is actually a complete computer in miniature. From the outside it looks like a little black box with 40 wire "teeth" on it (The technical term for them is "pins"). Inside that black box is an enormous amount of complex electronic circuitry.

This circuitry is similar to what used to be found in big computers. Because of some major engineering advances in recent years, it has become possible to miniaturize all of that circuitry and pack it into a tiny area. Don't be fooled by the smallness of the 8500 -- it is a very powerful computer. Some of it's capabilities are as follows:

It can be programmed in "6502 machine language". This is the language which has been mentioned several times in the book. You saw an example of it in the previous chapter.

It can process machine language commands at speeds approaching 1 million commands per second.

Although the 8500 has very little memory of its own (only about a dozen bytes), you may attach to it hundreds of thousands of bytes of memory.

The 8500 is a "stripped down" computer, it comes without a keyboard, screen, disk drive, printer, or any other "peripherals". However it allows peripherals to be attached to it. It is possible to attach dozens of peripherals to the 8500 at one time.

Obviously the 8500 does not look like the usual computer that you see in a computer store. Here are the main differences between a 8500 and a regular microcomputer:

An 8500 is much smaller and cheaper (An 8500 can be

bought for only a few dollars).

An 8500 comes with very little memory -- only about a dozen bytes. (However it is possible to attach additional memory to a 8500).

An 8500 comes without any peripherals such as a disk drive, screen, or keyboard.

While it is possible to "hook up" various devices to a 8500,it's hard work. Let's make a comparison: If you want to hook up a printer to your COMMODORE-128, all you have to do is go to a computer store, and buy a printer that is advertised as being compatible with the COMMODORE-128. Then you go home and plug it into the back of your computer. If you wanted to hook up a printer to a 8500, here are some of the problems you would be up against:

An 8500 doesn't have any sockets for you to plug a printer cable into ! You would have to design a socket, and figure out what pins on the 8500 to attach it to.

An 8500 does not know how to communicate to a printer. In order to make a printer print, you need to send it various streams of signals, transmitted at a certain precise speed. You also have to be able to receive and understand various signals that the printer may send to you, such as the signal for "I am out of paper". A 8500 does not know how to do any of this. In order for a 8500 to communicate properly with a printer, you would have to write a series of machine language programs that "teach" the 8500 how to communicate.

An 8500 does not know how to handle problems that can occur when a printer is operating. For instance, the 8500 does not know what to do if the printer is sending signals that it is busy, or if it is getting no response from the printer. Programs must be written that tell the 8500 how to detect problem conditions, and how to respond to them.

Memory. There are several different kinds of memory in your COMMODORE-128.

First, there is the small amount of memory that is in the 8500. This memory is divided into units called registers. Each

register holds 16 bits or 8 bits. Registers are used by the 8500.as little scratch pads to hold information which it currently needs. This memory is not accessible through BASIC.

Second, there is 128K of "read-write memory", or RAM as it is more commonly called. RAM is defined as memory where information may be stored, altered, or erased. When you turn off the computer, all information in RAM is lost. Inside your computer, RAM takes the form of 8 little black boxes called "RAM chips". Each RAM chip holds 8K.

The 8500 can operate on only 64K at a time! At a number of points in this book, we have discussed the concejpt of banks. We have explained that banks are necessitated by the inability of certain components of the C-128 to operate on more than 64K at a time. One such component is the 8500 chip. In computer jargon we would say that "the 8500 can address only 64K". Fortunately, by means of banking, we can effectively increase the processing abilities of the 8500 far beyond 64K.

Third, there are three important units of "read-only memory" (ROM). ROM is memory which has information permanently frozen into it. This information may be read, but it may not be altered or erased. The three ROM units are:

Character ROM (4K): This holds the shape tables for all symbols that can be drawn by the computer.

BASIC Interpreter ROM (Approximatly. 16K): This holds the machine language routines for processing BASIC commands.

KERNAL ROM (8K): This holds the machine language routines for the KERNAL. The KERNAL is responsible for the some of the most fundamental tasks of the computer, such as making the cursor blink.

The work done by these units was discussed in Chapter 7, THE MAP OF MEMORY.

Fourth, most peripherals, and most "special-purpose" units (such as SID), have at least a little of their own memory, reserved for their own use.

Finally, it is useful to remember that disk drives also are a kind of memory. They are used mainly to store large quantities of information for a long period of time. Also, they can be used as a spillover area when other memory gets filled. For instance: If you write a program which is too large to fit into memory, you could split it into two parts, and store each part as a separate program on the disk. When you run the program, just one of the two parts can be kept in memory; and when the other part is needed, it can be loaded from the disk.

Communications lines. In order for the 8500 to communicate with memory and the other parts of the computer, some communications lines are needed. There are two ways that the 8500 is linked up to other devices.

In some cases there are special lines directly betweenthe 8500 and other devices. For instance, if you are storing a program on a cassette recorder, there is a direct line between the cassette recorder and the 8500, which tells the 8500 when it is okay to begin sending data over to the cassette.

In other cases, there are communications lines which run through the computer, that many devices can "tap into". A communications line like this is known as a "bus". A bus is like a road that many different electrical signals can travel on. Many devices may be tapped into the same bus. All messages sent on a bus are accompanied by additional signals which "identify them". That way, each device knows which signals are for it, and which to ignore.

The "bus" concept makes it possible for a very large number of devices to be attached to the computer. Each device is tapped into the bus, and is assigned a code which identifies it. Any signals for that device are identified with its code.

Add-ons (Peripherals). Some of the peripherals you already know include the following:

Keyboard
Screen
Cassette recorder
Disk drive
Printer
Joystick

Modem

Each of these peripherals is able to communicate with the 8500 through the buses. The communications protocols can become quite complex. For instance, if you are SAVEing a program on disk, the computer must

Verify that the disk drive is on

Tell the disk drive to get ready to receive some information

Send the data to the disk drive

Check to make sure that the data has been received by the disk drive

Actually, even more steps than this are required. For those steps to be carried out, a number of signals must be sent and received by the 8500.

Special devices. If the 8500 had to do everything all by itself, the speed and performance of your computer would be hampered. So the designers of the COMMODORE-128 equipped it with a number of special-purpose devices. Each device specializes in certain kinds of tasks. Here are the most important special devices.

6581 Sound Interface Device (SID): You have already learned a lot about SID. SID is a special-purpose microprocessor whose sole job is to create sounds and music.

8566/8567 Video Interface Controller (VIC-II): VIC-II is a special-purpose microprocessor which is responsible for everything that happens on the screen. Whenever the 8500 wants something to happen on the screen, the 8500 sends a message to the VIC-II, and VIC-II takes care of the rest. A few examples of what VIC-II can do:

Display the letter "Q" in yellow in the upper left-hand corner of the screen.

Make the border of the screen red.

Move sprites around the screen.

Make the screen scroll.

6526 Complex Interface Adapter (CIA): CIA is "switchboard central" for signals that are traveling between the computer and its peripherals. It makes sure that none of the signals interfere with each other or get lost. There are so many signals traveling through your computer, that two CIAs are needed to keep all of the signals under control.

Now, we can summarize in just a few paragraphs, how the COMMODORE-128 works:

The part of the computer that "runs the whole show" is the 8500. The 8500 is a tiny computer that can process commands written in 6502 machine language.

Your computer's memory at all times holds a large number of machine language programs for all the elementary tasks that are required to run a computer. If you take a snapshot of the 8500 at any time, you will discover that it is always executing one of these programs.

The 8500 can control other devices by sending signals to them through communications lines. Some of these devices are there for your benefit -- e.g., the screen, the keyboard, the printer, and so on. Other devices are there to perform special jobs. For instance, SID is in charge of sound, and VIC II is in charge of the screen. The CIAs act as "switchboards" to keep all of the signals under control, that are traveling around the computer.

The 8500 can also receive signals from other devices through the communications lines. Depending on what signals are received, the 8500 decides what it is going to do next.

So in summary, the 8500 is the primary "thinking organ" in the computer. Its behavior is made more intelligent by means of the many machine language programs which reside in memory. These programs tell the 8500 how to perform the many different tasks that it must perform. The 8500 gets help from special-purpose devices such as SID, VIC-II, and the CIAs. The 8500 can tie in with many other devices through communications lines.

CHAPTER 17
CONCLUSION

You have reached the end of our introductory tour of the internals of the COMMODORE-128. We would now like to draw some final conclusions, and make some suggestions for how you can best continue learning about the COMMODORE-128.

So far, we have presented three rules of Computer Snooping:

1. *The computer is an alien form of lower intelligence.*

2. *You can learn a lot about how your computer works by running experiments.*

3. *Your computer system is built up in layers.*

To these we add a final rule:

4. *To understand your computer, find out about*

Codes
Pointers
Languages
and Maps

that pertain to your computer.

By codes we mean **ASCII**, binary, the codes for variable types, the codes that represent the various commands in BASIC, the codes for representing the value of floating-point variables, and so on. As you have discovered, the computer uses codes extensively to put information in a form that is convenient for its own use. These codes often look

horrendous the first time you see them. But, we have seen that it often is possible to make sense of them pretty quickly. Of course, it helps a lot to have good reference sources to explain the codes, and we will suggest some shortly.

By **pointers** we mean the computer's way of designating various locations in memory. Your computer uses pointers extensively. Pointers are often tedious to trace, but the main concept of pointers can be grasped fairly quickly. When you deal with pointers, make sure you understand the exact rules that the computer uses to determine the meaning of a pointer.

The key language for the COMMODORE-128 is 6502 machine language. A knowledge of that language is very useful for snooping. There are also some minor languages that are useful to know, for instance the "language" of codes that the COMMODORE-128 uses for communicating with various peripherals.

Maps tell you where things are inside the computer. In this book we have given you some maps -- For instance, a general map of memory, and a detailed map of the portion of memory that controls the screen. There are other maps that are useful, for instance a map of certain reference tables in the early parts of memory.

If you keep in mind **codes, pointers, languages, and maps**, this can help you to progress more quickly as a computer snooper.

Now, for some books that can help you in the future:

1. **COMMODORE-128 SYSTEM GUIDE.** Besides presenting BASIC, and elementary operational matters, this manual presents useful information relating to codes and maps. Also, there are many excellent sample programs throughout the manual, that will help you to explore the capabilities of your computer. The information that you will want is scattered throughout the manual. However, the manual is fairly easy to read, and is worth going through for whatever useful information it can provide.

2. **COMMODORE-128 PROGRAMMER'S REFERENCE MANUAL.** This is crammed with useful information for snoopers -- a large amount of detailed

information of codes, pointers, languages, and maps. The manual is very detailed, and sometimes it is tough reading. But even if you only can understand a small percentage of the material, a great deal can be learned.

3. **VIC-1541 SINGLE DRIVE FLOPPY DISK USER'S MANUAL** (and the update of the manual for the 1571 Disk Drive). This little book is crammed with useful information on the disk. Like the COMMODORE-128 PROGRAMMER'S REFERENCE MANUAL, it is sometimes difficult reading.

4. **ASSEMBLY LANGUAGE FOR KIDS: COMMODORE 64 & 128.** This general beginner's book will help you get started programming in machine and assembly language in both the C-64 and C-128 modes. There is a full discussion of how to write programs using the built-in monitor inside the machine as well as detailed instructions on using different types of popular assemblers. In addition, you learn how to program in machine/assembly language in a step-by-step fashion that makes it very easy. When you're finished you will be able to program everything from text to sprites!

In addition to reading, we encourage you to continue with your own direct investigations of the COMMODORE-128. To help you along, we have added a long chapter of EXTRA TOPICS in Appendix A. Most of these topics are presented in an open-ended manner, so that you can use them as a starting point for your own adventures.

Have fun!

APPENDIX A. ADVANCED TOPICS

1. A PROGRAM TO SEARCH THROUGH MEMORY

Suppose you want to find something in memory, but you don't know where it is. For instance, you might want to find all of the error messages that are in memory. One way to do this, of course, would be to use SNOOP, and look at each part of memory. This would take a very long time! The following program provides an easier way. It allows you to INPUT a string into a variable S$, and then the program will print all of the locations in memory which match the string.

RUN THIS PROGRAM:

```
1 REM SEARCHER
100 PRINT CHR$(147);
110 INPUT "SEARCH FOR ";S$
200 S1=ASC(S$)
210 LS=LEN(S$)
300 FOR L=0 TO 65535
310 IF PEEK(L)=S1 THEN GOSUB 900
320 NEXT L
330 END
900 T$=""
910 FOR I=1 TO LS
920 P=PEEK(L+I-1)
930 T$=T$+CHR$(P)
940 NEXT I
950 IF S$=T$ THEN PRINT L;
960 RETURN
```

The computer will ask you

SEARCH FOR?

Let's have it search for all occurrences of the word "ERROR".

Type the word ERROR and press RETURN.

The computer will scan through memory from beginning to end, and whenever it finds the word "ERROR", it will display the location on the screen. After the program is finished, you can use SNOOP to go back and look at each of the locations in memory.

Searching through memory requires creative thinking. For instance, in this example, we might not pick up all error messages by looking for the word "ERROR". Some error messages may use the abbreviation "ERR". Also some error messages use neither of these, they may use the word "ILLEGAL" instead.

For some searches, you will want to modify this program. For instance, if you wanted to search only locations 40000 - 50000, you could change line 300 to

```
300 FOR L=40000 to 50000
```

You might also modify the program to actually print out some of the information that it finds in memory, in addition to the locations of information.

Remember that your program and its variables are held in memory, and this will affect what is "discovered" during the search. For instance, when the program scans through the area where the contents of S$ are stored, it will pick up a "match".

One other tricky matter to keep in mind: The computer uses several systems of codes to store information in memory. This particular version of the program is designed to locate information that is in ASCII codes. If you are looking for information which may be expressed in other codes, you will need to adapt this program.

HOW SEARCHER WORKS:

The first few lines of the program set up several important

variables:

S$ is the string you are searching for.

S1 is the ASCII value of the first character in S$. For instance, if S$ = "ZYGOTE", then S1 is 90, which is the ASCII code for "Z".

LS is the length of S$.

The program proceeds to search through memory, byte by byte. The variable L keeps track of what location we are on.

The key line in the program is line 310

```
310 IF PEEK(L)=S1 THEN GOSUB 900
```

This command PEEKS into each byte, to see if it has the value S1. If it does, then this might be the beginning of an occurrence of S$. In that case, the command tells the computer to carry out the subroutine at line 900. That subroutine checks to see if this is an actual occurrence of S$.

2. "NEW" DOES NOT ACTUALLY CLEAR MEMORY.

If you run a program, wait until it's finished, and then type NEW, this seems to clear the program and its variables from memory. After you type NEW, if you type LIST, nothing will appear. Also, if you try to PRINT any of the variables from the program, all of their values will have been erased.

Now actually, most of the program and variables are still in memory. The main thing that happens when you NEW a program, is that some pointers to the program and the variables get "cut off". Once these pointers are cut off, the computer no longer "believes" that your program or variables still exists. Actually, most of the residue is still there. We are going to run a program, NEW it, and then look at the residue of the variables.

RUN THIS PROGRAM:

```
1 REM LOTSA
100 DIM A$(255)
200 FOR I=65 TO 69
```

```
210 R=255*RND(1)
220 A$(R)=A$(R)+CHR$(I)
230 NEXT I
240 C=C+1:PRINT C:IF C<5000 THEN 200
```

This program builds up a group of variable strings, which consist of random combinations of the letters A, B, C, D, and E.

When the program is finished, type NEW and press RETURN to "clear" the program and variables.

Now load in SNOOP, add the following line to SNOOP:

```
100 INPUT "BANK": BA: BANK BA
```

Now RUN SNOOP. When prompted for a bank type 1 and RETURN. This will cause SNOOP to focus on the bank where variables are stored. When it asks you START AT?, type 50000 and press RETURN. You will see a display something like this:

```
START= 50000

 A   B   D   E   E   B   B   A
65  66  68  69  69  66  66  65
 B   B   A   C   C   C   A   E
66  66  65  67  67  67  65  69
 D   A   C   D   D   B   B   B
68  65  67  68  68  66  66  66
 A   A   B   E   E   D   E   C
65  65  66  69  69  68  69  67
 C   B   E   D   E   D   B   B
67  66  69  68  69  68  66  66
 B   B   A   E   C   B   E   A
66  66  65  69  67  66  69  65
 D   B   A   E   D   C   A   A
68  66  65  69  68  67  65  65
 C   A   D   D   C   E   B   B
67  65  68  68  67  69  66  66
 E   A   D   E   D   E   E   C
69  65  68  69  68  69  69  67
 C   C   E   D   A   D   B   A
67  67  69  68  66  68  66  65
```

START AT?

You are looking at a portion of memory where some of the variable data was stored in the previous program.

3. HOW TO UN-NEW A PROGRAM

We just saw how NEW does not really clean variable data out of memory. The same program holds for the program itself. When you NEW a program, all of the text for the program actually still remains in memory. All that has been eliminated is pointer information. If you POKE the pointer information back in, the program will reappear! The following example will demonstrate how this is done.

Before entering this program, clear your computer completely by turning it off, waiting ten seconds, and turning it back on. Then

ENTER THIS PROGRAM EXACTLY AS WRITTEN

```
1 REM UNNEW
100 PRINT "HERE IS NOW TO UN-NEW ME:"
110 PRINT
120 PRINT "POKE 7169,";PEEK(7169)
130 PRINT "POKE 7170,";POKE(7170)
```

When you RUN the program, it will display instructions for recovering the program after it has been NEWed. RUN the program. You will get a display something like this:

```
HERE IS HOW TO UN-NEW ME:

POKE 7169, 22
POKE 7170, 28
```

(The numbers on your screen may be different from the ones in our illustration.)

The computer has given you instructions for recovering this program after it has been NEWd. Let's NEW the program, and then try to recover it.

Type NEW and press RETURN. This will "clear" the program.

Type LIST and press RETURN. Nothing will appear. The program is "gone".

Now let's recover the program. Enter the two POKE commands which appeared on your screen a moment earlier. In our illustration these commands were:

POKE 7169, 22
POKE 7170, 28

Use the POKE commands which appeared on your screen.

Now, type LIST and press RETURN. The program has appeared again. Congratulations! You have un-NEWd a program!

Here's how it worked:

The two values that you POKEd are the first two bytes in the program. They are a pointer. They point to the second line in the program.

When you NEW a program, the computer changes both of these bytes to 0. This signals to the computer that there is no program at all. Actually, the entire text of the program is still right where it was in memory. When you change the 0's back to their original values, your program is "restored".

To un-NEW a program, you have to know what values to change those two 0's back to. In this case it was easy because the program was designed to tell you what the values were supposed to be. In "real life" cases, you will probably have to do some guesswork. The correct value for the pointer will depend on the length of the first line of the program. The longer that line, the higher the value of the pointer at the beginning of the program. If you want to become an expert at un-NEWing programs, play around with a few examples, and you will soon get the hang of it.

Warning: There are pitfalls in the procedure we have described. This is because there are other pointers relating to your program which may have been altered after you entered the NEW command. Our procedure should enable you to LIST the program, and you will probably be able to RUN it at least once. But you may get unexpected effects if you use the

program more than that. If the program is important to you, you should re-enter it.

4. GETTING USED TO NUMBER SYSTEMS AND CODES

Part of becoming a good computer snooper is getting used to base two (binary) and ASCII. The following programs will help you to get familiar and comfortable.

This first program will help you to relate binary and ASCII to base ten.

RUN THIS PROGRAM:

```
1 REM CODES1
100 PRINT CHR$(147);
110 INPUT "ENTER A NUMBER (0-255)";N
120 PRINT "BASE TEN IS: ";N
200 PRINT:PRINT "BINARY IS:  ";
210 V=N
220 T=128
230 FOR I=1 TO 8
240 IF V < T THEN PRINT "0";:GOTO 260
250 PRINT "1";:=-V-T
260 T=T/2:NEXT I
290 PRINT
300 PRINT "ASCII SYMBOL IS: ";CHR$(N)
```

The computer will ask you to

```
ENTER A NUMBER (0-255)
```

Type 90 and press RETURN. On your screen you will see:

```
BASE TEN IS: 90
BINARY IS:  01011010
ASCII SYMBOL IS: Z
```

The computer is showing you the "counterparts" of 90 in binary and ASCII. Try some other values, and keep working with this program until get used to the relationship between these systems. **Warning**, there will be a few values which will cause strange behavior on the screen. This is because some ASCII codes, such as 147, do not generate symbols,

rather they are "screen control" codes. For instance, 147 is the screen control code for clearing the screen. PRINT CHR$(147) does not print a symbol, rather it clears the screen.

The next program deals with the same systems, but in a different way.

RUN THIS PROGRAM:

```
1 REM CODES2
100 PRINT CHR$(147);
110 INPUT "ENTER A CHARACTER ";A$
115 N=ASC(A$)
120 PRINT "BASE TEN IS: ";N
200 PRINT:PRINT "BINARY IS:  ";
210 V=N
220 T=128
230 FOR I=1 TO 8
240 IF V < T THEN PRINT "0";:GOTO 260
250 PRINT "1";:V=V-T
260 T=T/2:NEXT I
290 PRINT
300 PRINT "ASCII SYMBOL IS: ";CHR$(N)
```

When you run this program, it will ask you to enter a character. Type Z and press RETURN. On your screen you will see:

```
ENTER A CHARACTER? Z
BASE TEN IS: 90
BINARY IS:  01011010
ASCII SYMBOL IS: Z
```

The ASCII value (in base ten) of "Z" is 90. The last three lines show 3 equivalent forms for the same value.

One other number system you will eventually need for computer snooping is base 16, also known as "hexadecimal" of "hex". Hex is like base ten, except that instead of using just ten symbols for counting, it uses 16 symbols. Those symbols are:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E

The following chart compares a few numbers expressed in base ten, and hexdecimal.

BASE TEN	HEXADECIMAL
0	0
1	1
9	9
10	A
11	B
12	C
13	D
14	E
15	F
16	10
17	12
19	14
31	1F
32	20
64	40
128	80
254	FE
255	FF
256	100
65535	FFFF

Hexadecimal notation is often a very convenient method for describing what is in the memory of the computer, and for discussing machine language. You will often encounter hexadecimal when you read technical books and articles about computers.

This next program will give you some practice in comparing base ten and hexadecimal.

```
1 REM HEX
100 T$="0123456789ABCDEF"
110 DIM T$(15)
120 FOR I=1 TO 16
130 T$(I-1)=MID$(T$,I,1)
140 NEXT I
200 INPUT "NUMBER (0-255)";N
210 L=INT(T/N)
220 R=N-16*L
300 PRINT "BASE TEN IS: ";
310 PRINT "HEX IS: "; T$(L);T$(R)
```

This program will simply ask you to enter numbers in base ten, and then it will display the hexadecimal equivalent. By the way, lines 100 - 140 simply set up an array T$() where T$(0)="0", T$(1)="1", and so on up to T$(14) ="E" and T$(15)="F".

If you would like to learn more about hexadecimal notation, it is discussed in the COMMODORE-128 PROGRAMMER'S REFERENCE GUIDE, as well as most middle-level technical books on the COMMODORE-64.

5. SEE AND HEAR BINARY

All information that the computer handles is expressed in bits - - just 1's and 0's. Human beings rarely like to see information this form, because it is so hard to read and interpret. However, there are times when you want to see information in binary. The following program shows a method for converting any set of bytes to binary. It allows you to INPUT a message into a variable M$. Then it prints the binary version of M$. The program also includes some sound effects, so that you can "hear" binary. (This is similar to what data "sounds" like when it is sent and received by a disk drive or cassette recorder.)

RUN THIS PROGRAM:

```
1 REM INBIN
10 SD=54296:POKE SD,0
20 FOR I=1 TO 10:POKE SD-I,67:NEXT I
100 PRINT CHR$(147);
110 INPUT "MESSAGE ";M$
120 PRINT
200 FOR P=1 TO LEN(M$)
210 V=ASC(MID$(M$,P,1))
300 T=128
310 FOR I=1 TO 8
320 IF V<T THEN PRINT "0";:POKE 54287,40:GOTO 400
330 PRINT "1";:POKE 54287,70:V=V-T
400 GOSUB 900
410 T=T/2
420 NEXT I
500 PRINT " ";
510 POKE 54287,255:GOSUB 900
520 NEXT P
```

```
530 END
900 POKE SD,15
910 FOR Z=1 TO 100:NEXT Z
920 POKE SD,0:RETURN
```

HOW INBIN WORKS:

Lines 100 - 110

When the computer asks you to enter a message, type "PZAZ" and press RETURN. On your screen you will see

```
MESSAGE? PZAZ

01010000 01011010 00100001 01011010
```

The second line is the binary version of "PZAZ". Since each character in the message translates into 8 bits, a space is added after each 8 bits for readability. As the bits are being displayed on the screen, you will hear a series of tones -- a high tone for each "1" and a low tone for each "0", and a very high tone between each group of 8 bits.

HOW INBIN WORKS:

Lines 10 - 20

```
10 SD=54296:POKE SD,0
20 FOR I=1 TO 10:POKE SD-I,67:NEXT I
```

are a standard way of setting up the computer to make a simple sound. This method is discussed in Appendix B -- NOTES ON BASIC FOR COMPUTER SNOOPERS. If you like, you can just think of it as a "black box". Once these lines have been placed at the beginning of a program, you can start a tone with

```
POKE SD,15
```

and you can stop the tone with

```
POKE SD,0
```

You can vary the pitch of the tone by POKEing various values to location 54287 (The higher the value, the higher the pitch.)

Lines 100 - 110

```
100 PRINT CHR$(147);
110 INPUT "MESSAGE ";M$
```

clear the screen, and allow you to INPUT a message into M$.

Lines 200 - 520

```
200 FOR P=1 TO LEN(M$)
.
.
.
520 NEXT P
```

is a big FOR - NEXT loop. Each time the computer passes through the loop, it translates one of the characters of M$ into binary.

Line 210

```
210 V=ASC(MID$(M$,P,1))
```

extracts one of the characters from M$ and translates it into it's ASCII code. For example, suppose M$ is "HI MOM!" and P is 2. Then V would be set to 73, which is ASCII for the letter "I".

Lines 300 - 330 translate the code in V into binary. Let's trace through how it works, using V = 73 as an example:

V	I	T	Bit	New value for V
73	1	128	0	73
73	2	64	1	9
9	3	32	0	9
9	4	16	0	9
9	5	8	1	1
1	6	4	0	1
1	7	2	0	1
1	8	1	1	0

If you read the 8 bits off the Bit column from top to bottom, you will get 01001001 which is the binary equivalent of 73 (base ten).

The way lines 300 - 330 work is to whittle down V to 0 in eight steps. In the first step we try to subtract 128 from V, then 64, then 32, then 16, 8, 4, 2, and 1 successively. We perform a subtraction only when V is at least as big as the number we want to subtract. Depending on whether a subtraction can be performed or not, the program displays a "1" or a "0" on the screen.

The sound effects work like this: Whenever a "1" bit is to be displayed, we have the command

```
POKE 54287,70
```

This sets up SID to produce a high pitch.

Whenever a "0" bit is to be displayed, we have the command

```
POKE 54287,40
```

This sets up SID to produce a lower pitch.

After every 8 bits the following command is executed:

```
POKE 54287,255
```

This sets up SID to produce a very high pitch (you may not even hear it).

The pitches are actually turned on and off by the subroutine starting at line 900

```
900 POKE SD,15
910 FOR Z=1 TO 100:NEXT Z
920 POKE SD,0:RETURN
```

Line 900 turns on the sound, line 910 is a time delay, and line 920 turns the sound off and RETURNs.

6. POKING INTO A VARIABLE

Earlier in the book, we used VARLOOK2 to see what a floating point variable looks like in memory when it holds various values. Now we are going to do the reverse: We will create a variable AB, find its location in memory, POKE some values into it, and see what happens.

RUN THIS PROGRAM:

```
1 REM VARPOKE
10 BANK 1
20 AB=0
100 B= PEEK(47) + 256*PEEK(48) + 2
200 PRINT "AB = ";AB
210 FOR I=B TO B+4
220 PRINT PEEK(I);
230 NEXT I
240 PRINT:PRINT
300 INPUT "POSITION TO POKE (0-4) ";P
310 INPUT "VALUE TO POKE (0-255) ";V
320 POKE B+P,V
330 PRINT:GOTO 200
```

The program will ask you for numbers to POKE into positions 0, 1, 2, 3, and 4. These five positions control what value the variable AB has. Here are a few sets of numbers to try:

POSITION					
0	1	2	3	4	VALUE OF AB
0	0	0	0	0	0
128	0	0	0	0	.5
128	128	0	0	0	- .5
128	128	128	0	0	- .501953125
128	128	128	128	0	- .501960754
128	128	128	128	128	- .501960784
1	0	0	0	0	2.93873588 E-39
1	1	0	0	0	2.96169475 E-39
1	1	1	0	0	2.96178444 E-39
1	1	1	1	0	2.96178479 E-39
1	1	1	1	1	2.96178479 E-39
1	1	1	1	4	2.96178479 E-39
1	1	1	1	5	2.9617848 E-39

7. RUNNING MACHINE LANGUAGE PROGRAMS

Earlier in the book we looked at an example of a machine language program. It is possible to enter that program into the computer and run it. Let's find out how to do this. The strategy for running a machine language program is as follows:

As you saw earlier, a machine language program is just a long sequence of bits.

To run a machine language program, the first step is to get all of those bits into memory. To do this, we use the POKE command, which stores data in memory 8 bits (1 byte) at a time. We must be careful to use an area of memory which is not being used for anything else.

Once the machine language program is in memory, it is ready to run. To run it, we use a special command in BASIC called SYS.

The following program takes care of getting our machine language program into memory, and starting it:

```
1 REM C64ML
100 FOR L=40000 TO 40064
110 READ V
120 POKE L,V
130 NEXT L
200 SYS 40000
300 PRINT "SUCCESS"
310 END
800 DATA 160,0,169,32
810 DATA 153,0,4
820 DATA 153,0,5
830 DATA 153,0,6
840 DATA 153,0,7
850 DATA 200,208,241
860 DATA 160,0
870 DATA 169,7,153,0,4,200
880 DATA 169,15,153,0,4,200
890 DATA 169,19,153,0,4,200
900 DATA 169, 8,153,0,4,200
910 DATA 160,0,169,7
920 DATA 153,0,216,200
```

```
930 DATA 153,0,216,200
940 DATA 153,0,216,200
950 DATA 153,0,216
960 DATA 96
```

Lines 800 - 960 are the actual machine language program. The numbers in the DATA statements are the values of the individual bytes of the machine language program. For instance, the first two bytes of your machine language program were:

```
10100000    00000000        (base two)
```

These translate into

```
160         0               (base ten)
```

And those are the first two values occurring in the DATA statements (see line 800).

To POKE this data into memory, we use the FOR - NEXT loop in lines 100 - 130:

```
100 FOR L=40000 TO 40064
110 READ V
120 POKE L,V
130 NEXT L
```

This loop READs the numbers in the DATA statements, one-by-one, and then POKEs them into memory starting at location 40000. This is an area of memory which is not usually used for anything else, so it is a "safe" place to put a machine language program.

After this loop is finished, the machine language program is ready to run. To start the machine language program, a SYS command is used:

```
200 SYS 40000
```

This command tells the computer "Run the machine language program which begins at location 40000".

The computer will then run the machine language program. In this example, the program clears the screen, and displays the word "GOSH" in the upper left-hand corner.

When the computer has finished the running the machine language program, it will automatically come back to your BASIC program, and pick up where it left off. In this case, it will come back to line 300

```
300 PRINT "SUCCESS"
310 END
```

If you try running C64ML, you will be amazed at how fast it runs. It finishes in less than a second. And almost all of that time was actually "set-up" time (the loop line lines 100 - 130).

The method we have described for running machine language programs is tedious, but it is "tried and true". Frankly, there is no really easy way to write machine language programs (That's the reason higher level languages like COBOL and BASIC were invented). However there is a method which is somewhat easier, and that is to use "assembly language". Assembly language is a programming language which essentially has the same set of commands as machine language; however the commands are expressed in numbers and letters rather than 1's and 0's. Assembly language looks like this:

```
5000 LDY #0
5002 LDA #32
5004 STA 1024,Y
```

Assembly language eliminates about 50% of the headaches of programming in machine language. To find out more about assembly language, a good way to start is to visit a computer store that specializes in software for the COMMODORE-128, and ask to see "assemblers" for the COMMODORE-128.

8. STOMPING THE OPERATING SYSTEM

There are several reasons why you might want to know how to stomp the operating system and cripple your computer system:

You have aggressive or destructive tendencies!

You want to find out about things you should not do, so you will not do them.

You want to write programs that have powerful security features in them. (One kind of security strategy is to design a program so that if someone misuses it, the program will disable the computer system.)

Whatever your motives, here is an example of a program that stomps the operating system.

RUN THIS PROGRAM:

```
1 REM STOMP
100 PRINT "GOODBYE ... ":PRINT
200 L=256
210 PRINT L
220 POKE L,0
230 L=L+1:GOTO 110
```

"GOODBYE ..." will appear on the screen. Then you will see numbers displayed on the screen as the program "stomps" on low memory byte-by-byte. When the counting stops, the operating system is dead. Your keyboard will not respond to anything that you type, not even STOP - RESTORE.

Don't worry, you didn't damage anything permanently. All this program does is wipe out some crucial data in memory. To bring your computer system "back to life", turn it off, wait ten seconds, and turn it back on.

HOW STOMP WORKS:

The lowest part of memory holds a large amount of important reference data for your computer system.

STOMP replaces a portion of the lowest part of memory with 0's. The result is that the computer loses some of the information that it needs to do its work. That is why the counting stops and the keyboard freezes.

9. LISTENING TO YOUR COMMODORE-64 WITH A RADIO

The COMMODORE-64 generates a great deal of radio frequency energy while it is running. The energy can be picked up and heard with an ordinary radio. The sounds that you get will depend on what tasks the computer is performing. Let's listen to what a few programs sound like

over the radio.

You will need an FM radio. Place it close by the computer, and tune it to 105 MHz. Then

RUN THIS PROGRAM:

```
1 REM RADIO1
2 REM PLAYS RANDOM TONES FOR RADIO
100 A = 100 * RND(1)
110 B = 10 * RND(1)
120 PRINT A,B
200 FOR I = 1 TO A
210 FOR J = 1 TO B
220 NEXT J
230 NEXT I
300 GOTO 100
```

You should hear a series of random tones over the radio, at the rate of 1 - 4 different tones per second. To get best reception on your radio, experiment with various positions near the computer. Also, try other frequencies on the FM or AM band. You probably will find several frequencies which give you reception, with some frequencies better than others. You may get good results at 100 KHz on the AM band.

The kind of sound which is produced is determined by a number of factors:

The execution speed of various commands or sections of the program.

The components of the computer which are involved in executing the program. There are a large number of electrical components in your computer, and different components throw off different kinds of electrical energy.

The frequency at which your radio is tuned. Different radio frequencies pick up different portions of the radio frequencies generated by the computer.

It would be very difficult to analyze in detail how and why the computer produces the particular sounds that it does. However it is possible to discover many interesting sound qualities by experimenting with various small programs.

With experience, you produce some very pure and interesting sounds, by means of the right programs.

Here are a couple of interesting programs to try:

RUN THIS PROGRAM:

```
1 REM RADIO2
100 INPUT A
110 FOR I=1 TO A:NEXT I
120 GOTO 100
```

This program allows you to hear what a FOR - NEXT loop sounds like. When the program asks you to enter a number, try one of these:

1000
3000
5000
7000
9000

The number that you enter will be the number of repetitions of the FOR - NEXT loop. You will hear different pitches at various times during the loop.

RUN THIS PROGRAM:

```
1 REM RADIO3
100 FOR I = 1 TO 255:A$ = A$ + "Z":NEXT I
110 A$ = "":GOTO 100
```

This builds up a string of "Z"s, one byte at a time, in the variable A$. When A$ reaches maximum length (255 characters), it is cut back down to zero-length, and the process repeats.

When you listen to this program, you will notice that the tone produced gets lower as the string gets longer.

10. MOVE SCREEN MEMORY TO VIEW OPERATING SYSTEM

This program relocates the screen memory to the first 1000 bytes of memory, to let you observe on the screen the computer using this area.

```
1 REM WATCHOS
100 POKE 2604,4
200 FOR I = 1 TO N
210 NEXT I
220 PRINT CHR$(7)
230 N=N+5: GOSUB 200
```

Line 100 is the poke that moves the screen to location $0000 the rest of the program is to create some activity that we can observe.

APPENDIX B. NOTES ON BASIC FOR COMPUTER SNOOPERS

The following notes will summarize some features of BASIC that are especially useful for snooping inside your computer.

1. FUNDAMENTAL TOOLS

The two most important tools for snooping are PEEK and POKE. PEEK allows you to find out the contents of any byte in memory. POKE allows you to alter the contents of any byte in memory (as long as it is not ROM memory).

To PEEK at a location in memory, simply indicate the location you want to PEEK at. For instance

```
PRINT PEEK(19449)
```

will display the value in location 19449.

To POKE a value into a location, indicate the location, and the value you want to store in that location. For instance

```
POKE 1039, 197
```

will store the value 197 in location 1039.

There are a few areas of memory where PEEKs and POKEs may not work as expected, because of special uses of those portions of memory. These are the areas where there is ROM memory, or where there is both "foreground" and "background" memory. These were discussed in Ch. VII, THE MAP OF MEMORY.

Also, bear in mind that some areas of memory are being updated frequently by the computer. So, if you POKE something into one of these areas, the computer may replace your POKE with new values almost immediately.

2. SCREEN DISPLAYS

To analyze what you find in the computer, you need some ways to display information neatly. The following tools are useful for that purpose.

To PRINT several pieces of information on the same line, use PRINT with commas or semicolons. For example, the following program

```
100 A=3:B=79:Q$="LULU"
110 PRINT A,B,Q$
120 PRINT A;B;Q$
```

will give you the following display on your screen

```
1      79     LULU
1   79 LULU
```

The following command will clear your screen, and position the cursor in the upper left-hand corner:

```
PRINT CHR$(147);
```

147 is the code for clearing the screen. It does the same work as the SHIFT-CLR combination from your keyboard.

The following command will position the cursor in the upper left-hand corner, without erasing the screen:

```
PRINT CHR$(19);
```

19 is the code for "home". It does the same work as the HOME key on your keyboard.

To indent from the left-hand side of the screen, use the TAB command.

The following example will illustrate these commands

```
100 PRINT CHR$(147);
110 PRINT:PRINT:PRINT"WILLY"
120 PRINT CHR$(19);
130 PRINT TAB(18);"FRED"
```

This program will print the word "FRED" at the center of the top line of the screen, and "WILLY" at the beginning of the third line of the screen. Here is what each line of the program does:

Line 100

```
100 PRINT CHR$(147);
```

clears the screen, and positions the cursor in the top left-hand corner.

Line 110

```
110 PRINT:PRINT:PRINT"WILLY"
```

prints the word "WILLY" on the third line.

Line 120

```
120 PRINT CHR$(147);
```

positions the cursor in the top left-hand corner of the screen, without erasing anything.

Line 130

```
130 PRINT TAB(18);"FRED"
```

moves the cursor 18 positions to the right, and prints the word "FRED".

The above techniques enable you display information any way you want on the first few lines of the screen. If you want to display information at other locations on the screen, the following routine can be useful.

```
1 REM ANYWHERE
10 RW$=CHR$(19);
20 FOR I=1 TO 24:RW$=RW$+CHR$(17):NEXT I
100 INPUT R,C
```

```
110 PRINT LEFT$(RW$,R);TAB(C);
120 PRINT "X";
```

When you run the program, it will ask you to INPUT values for the variables R and C. The program will then display an "X" at row R, column C on your screen. This program demonstrates how you can display information at any position you want on the screen.

Lines 10 - 20

```
10 RW$=CHR$(19);
20 FOR I=1 TO 24:RW$=RW$+CHR$(17):NEXT I
```

set up the crucial variable that makes the program work. RW$ consists of the code 19 followed by a series of 17s. 19 is the code for "home", and 17 is the code for "one line down". By PRINTing portions of this variable, you can move the cursor a certain number of lines down from the top of the screen, to the row which you want.

Line 110 is the line that positions the cursor in the row and column which you want.

```
110 PRINT LEFT$(RW$,R);TAB(C);
```

It prints a certain portion of RW$, just enough to move the cursor down to the row you want. The TAB(C); moves the cursor to the column on the screen which you want.

One other way you can position information on the screen, is by making POKEs to screen memory and color memory, as was discussed in Ch. 3.

3. MAKING SOUNDS

When you are analyzing complex information, the use of sound effects can be helpful. The following sample program will show you a simple way to create sound, with a minimum of POKEs to SID.

```
10 SD=54296:POKE SD,0
20 FOR I=1 TO 10:POKE SD-I,67:NEXT I
100 INPUT
110 POKE SD,15
120 INPUT
```

```
130 POKE SD,0
140 GOTO 100
```

When you RUN the program, at first you will hear nothing. Press RETURN once, and you will hear a tone. Press RETURN again, and the tone will turn off. Press RETURN again and the tone will turn on again. And so on.

Lines 10 and 20

```
10 SD=54296:POKE SD,0
20 FOR I=1 TO 10:POKE SD-I,67:NEXT I
```

set up the program to make sounds. Line 20 fills up the message area for Voice 3 with 67s. This will make a nice sound. Line 10 POKEs a 0 into the "volume control" for SID. This turns the sound off.

The sound is turned on by POKEing a 15 into the volume control. This is done in line 110

```
110 POKE SD,15
```

The volume is turned off again in line 130

```
130 POKE SD,0
```

The above sample program will create a sound with a constant pitch. If you want to vary the pitch, make various POKEs to location 54287, which helps to control the frequency for Voice 3.

4. MATHEMATICAL CALCULATIONS

If you need to round off a number, use INT. For example:

```
100 A = 1235.79
110 PRINT INT(A)
```

This program would print

```
1235
```

If you need the remainder from a division, the following sample program will show you how to obtain this.

```
100 A=80:X=7
110 Q=INT(A/7)
120 R=A - Q*X
130 PRINT Q,R
```

In this example the computer would print the following numbers:

```
11  3
```

If you divide 80 by 7, the quotient is 11 and the remainder is 3.

If you need random numbers, use the RND function. The following way of using it is usually satisfactory. Let's suppose you need a random integer in the range 0 - 99.

```
100 R = INT(100 * RND(1))
```

RND(1) will be a number between 0 and 1. So INT(100 * RND(1)) will be in the range 0 - 99.

Each time RND(1) is used in a program, it generates a new random number. Each time you run a program, the same sequence of random numbers is produced. (The numbers are not produced by chance. Rather they are generated by a special mathematical formula that generates a series of numbers which has the appearance of being random.). If this is not satisfactory, you need to find out about "seeding" the random number generator. This is discussed in your COMMODORE-128 USER'S GUIDE.

5. CONVERTING BETWEEN CODES, FORMATS, NUMBER SYSTEMS

The following functions will help you to get back and forth between various codes, formats, and number systems.

The ASC function gives the ASCII value of a character or symbol. For example

```
ASC("Z") is 90
```

The CHR$ function goes in the opposite direction. It converts a number into the ASCII symbol it stands for. For example

CHR$(90) is "Z"

Sometimes numbers are represented in string variables or need to be represented in string variables.

To create a string variable version of a number, use STR$. For example.

```
100 N = 237
110 N$ = STR$(N)
120 PRINT N$
```

The output would be: 237

The VAL function goes in the opposite direction. For example:

```
100 N$ = 976
110 N = VAL(N$)
120 PRINT N
```

The output would be 976.

6. RUNNING MACHINE LANGUAGE PROGRAMS

Before you can run a machine language program, you must learn several new concepts. To help you get started, an example is given in Appendix A of how to run a simple machine language program from BASIC.

The only special commands in BASIC that you need for machine language programming are

```
SYS
USR
```

Examples of the use of SYS are in Appendix A. To find out more about SYS and USR, see the COMMODORE-128 PROGRAMMER'S REFERENCE GUIDE.

7. MANAGING VARIABLES

If you want to clear all variables from the program, use the CLR command. This will not erase your program, only its variables.

To find out how much free space is available, use the FRE function. For example:

```
PRINT FRE(0)
```

will print the number of free bytes.

9. OTHER COMMANDS TO BE AWARE OF

You may know about these commands already, but to make sure, we will review them briefly.

LEN calculates the length of a string variable. For example

```
100 V$ = "MAMBO"
110 PRINT LEN(V$)
```

would display the value 5.

MID$ allows you to pick out a substring of a variable string. For instance,

```
100 V$ = "ABCDEFGHIJK"
110 PRINT MID$(V$,3,5)
```

would display   CDEFG

To join strings together, use "+". For instance

```
100 A$="YOO":B="HOO"
110 C$=A$ + B$
120 PRINT C$
```

would display

```
YOOHOO
```

DIM allows you to define a large set of variables in one fell swoop. For instance

```
100 DIM QU(173)
```

creates 174 variables. Their names are: QU(0), QU(1), QU(2), QU(3), and so on up to QU(172), QU(173).

APPENDIX C.
TECHNICAL NOTES

Ch. 2 -- Memory. Throughout this book, the concept of memory is refined several times.

In its most general sense, memory includes all capabilities in the computer for storing data. Types of memory would include: registers, RAM and ROM, disk and cassette storage, and special purpose memory devices (e.g., the RAM and ROM memory which resides in the disk drive unit).

Throughout most of the book, we are concerned primarily with that memory which is accessible via the PEEK and POKE commands. The PEEK command and the POKE command are each able to address a total of 64K bytes of memory at any time. We shall find out that there are some limitations on the abilities of PEEK and POKE. Also, we shall find out that there are some techniques which can extend the range of PEEK and POKE beyond 64K bytes.

PEEK and POKE can access only RAM and ROM memory. Later in the book, we will discuss other kinds of memory, especially disk memory and register memory.

Ch. 3 -- Invisible characters on the screen. If a certain area of the screen is blank, and you POKE a character into that area, you will not see anything happen on the screen. This is because the computer has assigned the same color to the character as the background of the screen. The character is "there" on the screen, but it is invisible, because it has the same color as the background.

When you POKE an appropriate color code into color

memory, this assigns a contrasting color to the character, and it then becomes visible.

Ch. 4 -- Shape tables. The shape table starts at location 53248 in BANK 14, and extends for 4096 bytes to location 57343. Since eachcharacter requires 8 bytes in the table, there are a total of 512 characters represented in the table. The first 64 characters in the table represent the characters which are produced be the keyboard in its normal mode. The remaining characters in the table are for lower case, graphics mode, and reversed characters. In our discussions in Ch. 4 and Ch. 5, we shall only be concerned with the first 64 characters (256 bytes) in the shape table. However, any of our sample programs may be modified in a straghtforward manner to encompass a complete 512 character table.

Ch. 5 -- Binary notation is hard to read. To reduce the difficulties of reading binary notation, computer people usually substitute "hexadecimal" ("hex") notation. In hex notation, each group of 4 binary digits is represented by 0, 1, 2, ..., 9, A, B, C, D, E, F. I.e.

BINARY	HEX
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

So for instance, the binary number 11010110 is represented as D6 in hex. Hex notation is much easier to read than binary notation. Hex notation is used widely in technical articles and books on computers.

Ch. 7 -- The computer is an alien form of lower intelligence. Some people would object to speaking of a computer as having intelligence.

When we speak of the computer as being a form of lower intelligence, we mean that the computer is capable of some kinds of behavior that are ordinarily thought of as requiring some intelligence. For instance, the computer is capable of responding correctly to sets of instructions in artificial languages such as BASIC. The computer is also capable of making generally appropriate responses to problem situations. For instance, if you enter the command

```
PRIMT 21 * 19
```

the computer will give you an error message, which will indicate that it cannot understand your command.

Some people would say of these examples that while they show that a computer is capable of complex and useful behavior, they do not show that a computer has any kind of "intelligence". This brings up a difficult issue of what intelligence is.

One view of intelligence equates intelligence with the ability to perform tasks which ordinarily require human intelligence. Under this view, a computer would qualify as having some intelligence, although not as much as human beings. Computers can perform such tasks as carry out commands in an artificial language, or play a competent game of chess. We think of these tasks as ordinarily requiring some human intelligence. So a computer qualifies as being intelligent to some degree.

Another view of intelligence is that it involves more than just the ability to perform tasks such as carrying out commands in an artificial language, or playing chess. Under this view, it is also important how the computer "perceives" or "understands" the situation that it is in. Importance is placed on not just what the computer does, but also how it does it, or perhaps on what goes on "inside" the computer. Under this view, the computer might be imagined as just a chunk of machinery which "goes through the motions" of acting intelligent, but actually is not capable of any intelligence of its own.

Both of these views can be elaborated into a number of different versions. All that we have done here is to sketch two views that are possible. It will not be necessary in this book to elaborate these issues further or to attempt to resolve them.

Our beliefs about the "intelligence" of the COMMODORE-128 may be summarized as follows:

The COMMODORE-128 is capable of performing some tasks which
ordinarily would require considerable human intelligence and effort.

The computer often uses methods for carrying out tasks which seem
primitive, by human standards.

We also believe that the computer is an "alien" form of intelligence, in that its methods for performing tasks are oftenradically different from human processes, and often incongenial to human understanding.

Ch. 15 -- 6502 machine language. Predcessors of the COMMODORE-128 were based on the MOS 6502 microprocessor. The C-128's microprocessor is a slight variant of the 6502 microprocessor. The machine language for the 8500 microprocessor and the 6502 microprocessor is identical. Because of this, it is usually said that the COMMODORE-128 is programmable in "6502 machine language".

Ch. 15 -- Assembly language. Writing programs in machine language is hard work. A somewhat easier way is to write programs in "Assembly language" instead. Assembly language is a programming language which essentially has the same set of commands as machine language; however, the commands are expressed in numbers and letters rather than 1's and 0's. See Part 8 of Appendix A -- EXTRA TOPICS.

Ch. 15 -- Hardware, other modes. In this 9book we have focused exclusively on this C-128 as it operates in the "C-128 mode". The other modes which we have not discussed: the "C-64 mode" and "CP/M mode".

When operating in the C-64 mode, the computer behaves as if it is a C-64. The hardware in the computer which is used for this purpose is essentially a subset of what is used in the C-128 mode.

When operating in CP/M mode, the computer acts as a computer with a CP/M operating system. In this mode, the computer does not utilize the 8500 CPU. Rather, it uses a separate CPU which is built into the computer: the "Z80-A" microprocessor.

APPENDIX D

BASIC TOKENS

A double set of tokens for BASIC exist in the Commodore 128. Values 128-202 ($0080-$00CA) represent the Commodore 64 tokens and the first part of the Commodore 128 BASIC 7.0 tokens. They are all set in lower case to emphasize they constitute the lower set. After 202, all tokens represent BASIC 7.0 tokens found only on the Commodore 128. Tokens after 254 are tokenized beginning at 1, but they still represent BASIC 7.0 tokens.

128 :$0080 end
129 :$0081 for
130 :$0082 next
131 :$0083 data
132 :$0084 input#
133 :$0085 input
134 :$0086 dim
135 :$0087 read
136 :$0088 let
137 :$0089 goto
138 :$008a run
139 :$008b if
140 :$008c restore
141 :$008d gosub
142 :$008e return
143 :$008f rem
144 :$0090 stop
145 :$0091 on
146 :$0092 wait
147 :$0093 load
148 :$0094 save
149 :$0095 verify
150 :$0096 def
151 :$0097 poke
152 :$0098 print#
153 :$0099 print
154 :$009a cont
155 :$009b list
156 :$009c clr
157 :$009d cmd
158 :$009e sys
159 :$009f open
160 :$00a0 close
161 :$00a1 get
162 :$00a2 new
163 :$00a3 tab(
164 :$00a4 to
165 :$00a5 fn
166 :$00a6 spc(
167 :$00a7 then
168 :$00a8 not
169 :$00a9 step
170 :$00aa +
171 :$00ab -
172 :$00ac *
173 :$00ad /
174 :$00ae ^
175 :$00af and
176 :$00b0 or
177 :$00b1 >
178 :$00b2 =
179 :$00b3 <
180 :$00b4 sgn
181 :$00b5 int
182 :$00b6 abs
183 :$00b7 usr
184 :$00b8 fre
185 :$00b9 pos
186 :$00ba sqr
187 :$00bb rnd

188 :$00bc log
189 :$00bd exp
190 :$00be cos
191 :$00bf sin
192 :$00c0 tan
193 :$00c1 atn
194 :$00c2 peek
195 :$00c3 len
196 :$00c4 str$
197 :$00c5 val
198 :$00c6 asc
199 :$00c7 chr$
200 :$00c8 left$
201 :$00c9 right$
202 :$00ca mid$

203 $00CB GO
204 $00CC RGR
205 $00CD RCLR
206 $00CE #
207 $00CF JOY
208 $00D0 RDOT
209 $00D1 DEC
210 $00D2 HEX$
211 $00D3 ERR$
212 $00D4 INSTR
213 $00D5 ELSE
214 $00D6 RESUME
215 $00D7 TRAP
216 $00D8 TRON
217 $00D9 TROFF
218 $00DA SOUND
219 $00DB VOL
220 $00DC AUTO
221 $00DD PUDEF
222 $00DE GRAPHIC
223 $00DF PAINT
224 $00E0 CHAR
225 $00E1 BOX
226 $00E2 CIRCLE
227 $00E3 GSHAPE
228 $00E4 SSHAPE
229 $00E5 DRAW
230 $00E6 LOCATE
231 $00E7 COLOR
232 $00E8 SCNCLR
233 $00E9 SCALE
234 $00EA HELP
235 $00EB DO
236 $00EC LOOP
237 $00ED EXIT
238 $00EE DIRECTORY
239 $00EF DSAVE
240 $00F0 DLOAD
241 $00F1 HEADER
242 $00F2 SCRATCH
243 $00F3 COLLECT
244 $00F4 COPY
245 $00F5 RENAME
246 $00F6 BACKUP
247 $00F7 DELETE
248 $00F8 RENUMBER
249 $00F9 KEY
250 $00FA MONITOR
250 $00FA MONITOR
251 $00FB USING
252 $00FC UNTIL
253 $00FD WHILE
254 $00FE $

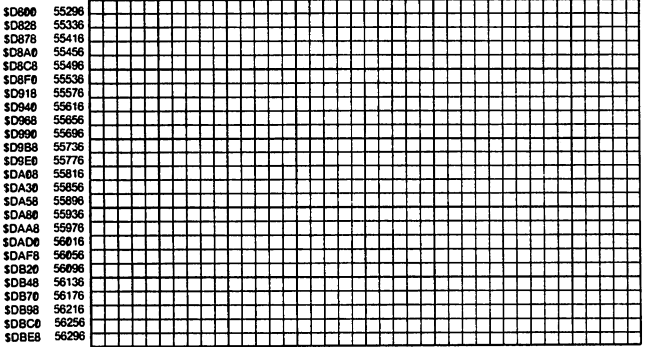
1 $0001
2 $0002 BANK
3 $0003 FILTER
4 $0004 PLAY
5 $0005 TEMPO
6 $0006 MOVSPR
7 $0007 SPRITE
8 $0008 SPRCOLOR
9 $0009 RREG
10 $000A ENVELOPE
11 $000B SLEEP
12 $000C CATALOG
13 $000D DOPEN
14 $000E APPEND
15 $000F DCLOSE
16 $0010 BSAVE
17 $0011 BLOAD
18 $0012 RECORD
19 $0013 CONCAT
20 $0014 DVERIFY

21 $0015 DCLEAR
22 $0016 SPRSAV
23 $0017 COLLISION
24 $0018 BEGIN
25 $0019 BEND
26 $001A WINDOW
27 $001B BOOT
28 $001C WIDTH
29 $001D SPRDEF
30 $001E QUIT
31 $001F STASH
32 $0020
33 $0021 FETCH
34 $0022
35 $0023 SWAP
36 $0024 OFF
37 $0025 FAST
38 $0026 SLOW

COLOR CODES

CODE	COLOR
0	BLACK
1	WHITE
2	RED
3	CYAN
4	PURPLE
5	GREEN
6	BLUE
7	YELLOW
8	ORANGE
9	BROWN
10	LIGHT RED
11	GRAY 1
12	GRAY 2
13	LIGHT GREEN
14	LIGHT BLUE
15	GRAY 3

COLOR STORAGE LOCATION TABLE



APPENDIX E

Using the Built-In Monitor and Mini-Assembler in the Commodore 128

MONITOR CONVERSION

For machine/assembly language programmers, the nicest thing added to the C-128 is the built-in monitor. Your System Guide explains the various commands (pp.369-378), and if you have not looked at that section of your Guide, you should do so before continuing. Here we'd like to explain how to use the mini-assembler.

To get started, key in MONITOR <RETURN> or just hit the SHIFTed F-8 key. You will now be in the monitor. You'll know since the major registers are displayed when you enter the monitor. First, it is important to understand that all default values in the 128 monitor mini-assembler are in hexadecimal. Take a look at Appendix C if you do not understand hexadecimal numbers. To enter decimal values, you must first place a plus sign (+) in front of the value and it will be entered as its correct value but changed into hex. For example, let's say you want to enter decimal 14. You would enter
+14
and it would be changed to
0E
Don't worry about what happened to your 14. It's simply been changed to 0E, the hexadecimal equivalent to decimal 14.
To convert between values, simply enter the value, with the appropriate sign before the value, and your monitor will automatically convert it to hex, decimal, octal and binary. Use the following symbols for your base conversion:
$ = hexadecimal
+ = decimal
& = octal
% = binary
Chapter 15 will explain what's going on, and as you program

more in assembly language you will come to appreciate and use this number converter more and more. Do the following to get started:

$1300 <RETURN>

You will be presented with:

$1300
+4864
&11400
%1001100000000000

You probably won't be using the octal values very much, but in examining the contents of registers and sprite configurations, the binary conversion will be very useful. Usually this conversion program will be converting between hex and decimal.

BUILT-IN C-128 MINI-ASSEMBLER

To assemble programs using mnemonic opcodes, enter:

A <address> <opcode> <operand>

For example, to enter programs in the Commodore 128 mode, you might start as follows:

A F1300 LDA #0D <RETURN>

As soon as you press the RETURN key, your code will look as follows:

A F1300 AD 0D LDA #$0D
A F1302

The 'AD 0D' are the machine language hexadecimal values for LDA and 0D. The next available address, F1302, is then presented for you to key in the next set of opcodes and operand. (*NOTE: In your **System Guide** the example on page 371 shows .A01200 ...etc. That is incorrect. You can use either the A or the period (.) to begin entering assembly code. It is an error to use them both together as in the **System Guide** example.)
Go over the **System Guide** instructions, practice with the mini-assembler and read pages 1-27 in this book to become familiar with entering code. Before we really get rolling, there is one more item to consider....banks.

BANKS

When you enter code in the monitor, you enter it in one of 16 banks ($0-$F). The fifth (left-most value) in an address is its bank value. For example:

F1300

^ bank value

means that the address 1300 is in bank F. The organization of information in Bank F is not the same as in Bank 0. (See page 370 of your **System Guide** for the different configurations for the banks.) The default bank when you turn on your C-128 is Bank 15 ($F), but when you enter code in the monitor, failure to enter the fifth value for an address puts you in Bank 0. However, to minimize confusion about banks, there are only two things to remember:

When writing code for the C-64 mode, use Bank 0.
When writing code for the C-128 mode, use Bank F.

PROGRAMMING FOR THE C-64 MODE

If you enter the code for the C-64 mode, you won't have to change anything from the published listings you will find. All you have to do is to key in the code from your built-in monitor, and when your are finished, go to the C-64 mode by entering the following from the monitor:

G FF4D

Once in the C-64 mode, simply SYS the beginning address of your program; usually 49152. (Of course you can eXit to BASIC by entering 'X <RETURN>' from the monitor, and then GO 64 from BASIC, but a real programmer will want to jump directly to the C-64 mode from the monitor.)

PROGRAMMING FOR THE C-128 MODE

While many of the addresses used for the C-128 mode are the same as the ones used in the C-64, many are different. For example, the pointers to the beginning of a BASIC program in the C-64 mode are $2B and $2C while in the C-128 mode they are $2D and $2E. Similarly, the often-used jump to

$E544 is something different in the C-128 mode, and the free RAM at $C000 (49152) in the C-64 is not free in the C-128.

C-128 mode is to access Bank F by putting in F as the first of 5 hex values when you initially begin assembling your code. Second, begin your programs at F1300 and NOT $FC000 or $F8000 or (even worse) $C000 or $8000. SYS 4864 from BASIC will automatically access $F1300. It is unnecessary to indicate BANK 15 ($F) since from BASIC, the default bank is 15. Once you have done your first line, you do not have continue entering the bank. This is done automatically. In referencing addresses from within the assembly language program, you do not have to reference banks for the level we will be discussing. The following shows the correct and incorrect way to reference addresses using the mini-assembler.

Incorrect
A F130E STA F1404 <-Adds the Bank number in the operand.
Correct
A F130E STA 1404 <-No Bank number in operand.

APPENDIX F
ASCII CHARTS

#	UC	UC/LC	#	UC	UC/LC	#	UC	UC/LC
0	@	@	51	3	3	102		
1	A	a	52	4	4	103		
2	B	b	53	5	5	104		
3	C	c	54	6	6	105		
4	D	d	55	7	7	106		
5	E	e	56	8	8	107		
6	F	f	57	9	9	108		
7	G	g	58	:	:	109		
8	H	h	59	;	;	110		
9	I	i	60	<	<	111		
10	J	j	61	=	=	112		
11	K	k	62	►	►	113		
12	L	l	63	?	?	114		
13	M	m	64			115		
14	N	n	65		A	116		
15	O	o	66		B	117		
16	P	p	67		C	118		
17	Q	q	68		D	119		
18	R	r	69		E	120		
19	S	s	70		F	121		
20	T	t	71		G	122		
21	U	u	72		H	123		
22	V	v	73		I	124		
23	W	w	74		J	125		
24	X	x	75		K	126		
25	Y	y	76		L	127		
26	Z	z	77		M			
27			78		N			
28			79		O			

29			80		P
30			81		Q
31			82		R
32	SPACE		83		S
33	!	!	84		T
34	"	"	85		U
35	#	#	86		V
36	$	$	87		W
37	%	%	88		X
38	&	&	89		Y
39	'	'	90		Z
40	(	(	91		
41	)	)	92		
42	*	*	93		
43	+	+	94	π	
44	,	,	95		
45	-	-	96		
46	.	.	97		
47	/	/	98		
48	0	0	99		
49	1	1	100		
50	2	2	101		

0	51 3	102	153 Lt Green	204
1	52 4	103	154 Lt Blue	205
2	53 5	104	155 Gray 3	206
3	54 6	105	156 Purple	207
4	55 7	106	157 CRSR left	208
5 White	56 8	107	158 Yellow	209
6	57 9	108	159 Cyan	210
7	58 :	109	160 SPACE	211
8 Sh-CMD off	59 ;	110	161	212
9 Sh-CMD on	60 <	111	162	213
10	61 =	112	163	214
11	62 >	113	164	215
12	63 ?	114	165	216
13 RETURN	64 @	115	166	217
14 Lowercase	65 A	116	167	218
15	66 B	117	168	219
6	67 C	118	169	220
17 CRSR down	68 D	119	170	221
18 RVS on	69 E	120	171	222
19 Home CRSR	70 F	121	172	223
20 Delete	71 G	122	173	224 SPACE
21	72 H	123	174	225
22	73 I	124	175	226
23	74 J	125	176	227
24	75 K	126	177	228
25	76 L	127	178	229
26	77 M	128	179	230
27	78 N	129 Orange	180	231
28 Red	79 O	130	181	232
29 CRSR right	80 P	131	182	233
30 Green	81 Q	132	183	234
31 Blue	82 R	133 f1	184	235
32 SPACE	83 S	134 f3	185	236
33 !	84 T	135 f5	186	237
34 “	85 U	136 f7	187	238
35 #	86 V	137 f2	188	239
36 $	87 W	138 f4	189	240

37 %	88 X	139 f6	190	241
38 &	89 Y	140 f8	191	242
39 '	90 Z	141 Sh-RETURN	192	243
40 (	91 [	142 Uppercase	193	244
41)	92 £	143	194	245
42 *	93]	144 Black	195	246
43 +	94 ↑	145 CRSR up	196	247
44 ,	95 ←	146 RVS off	197	248
45 -	96	147 CLR/HOME	198	249
46 .	97	148 INST	199	250
47 /	98	149 Brown	200	251
48 0	99	150 Lt Red	201	252
49 1	100	151 Gray 1	202	253
50 2	101	152 Gray 2	203	254
				255 π

GLOSSARY

ADDRESSABLE MEMORY: ROM and RAM memory which may be accessed by means of the PEEK, POKE and BANK commands. Contrast this with other parts of the computer which may be also called memory: Registers, disk memory, special purpose memory chips in the disk drive, etc.

ASCII: A code system which assigns a meaning to each of the byte values 0 - 127. For instance, `Q' is assigned to 81, and '!' is assigned to 33. 'ASCII' stands for 'American National Code for Information Interchange'.

ASSEMBLY LANGUAGE: A version of machine language which is more convenient for human beings to work with than machine language. The vocabulary of commands is the same, but the 1's and 0's of machine language are replaced by more meaningful symbols.

BAM (BLOCK AVAILABILITY MAP): A "map" on each disk which shows which sectors (blocks) are used, and which are unused.

BANK: A 64K subset of memory. Because of limitations of certain components (especially the 8500 CPU), the C128 is generally unable to process more than 64K of memory at any moment. To overcome this limitation, the C128 is equiped with a feature known as "banking". This feature allows the C-128 to select various 64K subsets. The result is that effectively the computer can operate on it's entire memory, even though it is limited to 64K at any moment.
There are 16 differnt standard subsets of memory, known as Bank 0 through Bank 15. The default bank is 15. The other most commonly needed banks are 0,1 and 14. These banks are discussed in Chapter 7, THE MAP OF MEMORY.

BASE: Refers to a number system e.g., Base Two (Binary), Base Eight (Octal), Base Ten (Decimal), or Base Sixteen (Hexadecimal or Hex).

BINARY: Base Two. In Base Two, the numbers from zero to eight are:0, 1, 10, 11, 100, 101, 110, 111, 1000 .

BIT: The smallest unit of information processed by the computer. A bit may have only two possible values, usually expressed as '1' and '0', or 'on' and 'off'. A set of 8 bits is called a 'byte'.

BOOT: Denotes the process that the computer must go through when it is started, before it is ready to respond to any of yourcommands. The process includes setting up certain reference tables in memory, clearing the screen, and displaying the initial greeting.

BUFFER: A temporary holding area for information before it reaches its final destination. For instance, when information is sent to the disk, the computer will sometimes accumulate a quantity of the information in a memory buffer, until a large enough amount has been obtained. And then all of the information in the buffer will be stored on the disk at the same time.

BUS: A communications line which runs through the computer. All major components are attached to the bus. The components may send signals to each other through the bus.

BYTE: A group of 8 bits. A byte may range in value from 0 to 255 (In binary: 00000000 to 11111111).

CHIP: Highly miniaturized electronic circuitry, compressed onto a tiny wafer of silicon (or similar material). Chips are usually packaged in a black protective housing, and the entire unit is often referred to as a chip. Examples of chips are the 8500 microprocessor, and SID (the chip that makes sound and music).

COMMAND INTERPRETER (COMMAND PROCESSOR): A program or set of routines that translates a human command into machine language commands which the computer can understand. For instance, when you issue the command 'PRINT 7 * (A + Q(3))', the computer cannot directly understand that command. However a command

interpreter, translates that command into machine language which can be understood by the computer.

COMPILER: A program which translates a program in a high-level language, such as BASIC or FORTRAN, into machine language.

CPU (CENTRAL PROCESSING UNIT): The 8500 microprocessor, which is the primary "thinking organ" of your computer.

CRT: The screen or monitor on which the computer displays information. 'CRT" stands for 'Cathode Ray Tube'.

DIRECTORY: The 'table of contents' for a disk -- the list of files on a disk.

DISK: A disk is used for long-term storage of programs and data files. The surface of a disk is composed of the same material as is used in a cassette tape. The circular shape of a disk increases reliability and performance, as compared to a cassette tape. A flexible plastic disk is known as a 'diskette' or 'floppy disk'. A high-storage-capacity disk on an inflexible metal disk is known as a 'hard disk'.

DISK CONTROLLER: The Commodore disk drive has built into it a microprocessor, memory chips, and "disk operating system" software, which help it to store, retrieve, and manage data on disks. The term "disk controller" refers to the collection of chips and operating system software built into the disk drive.

DUMP: A printout or screen display of the exact contents of an entire file.

FIELD: In the case of a mailing list file, examples of fields would be: Name, Address, City, State, and Zip. In the case of an inventory file, examples of fields might include: Part number, description, quantity-on-hand, cost, and selling price.

FILE: A collection of data which is stored on the disk under one name. The name of each file is stored in the disk directory.

MEGABYTE: One million bytes, or 1000 K bytes.

HARD DISK: See DISK.

HEX (HEXADECIMAL): Base 16. In Hex, the numbers from zero thru 20 are: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, 10, 11, 12, 13, 14.

INTERPRETER: A program or set of routines that enables the computer to process commands in a high-level language such as BASIC. For each command in the high-level language, the interpreter translates the command into machine language, tells the computer to execute it, and then goes on to the next high-level command. Contrast this with a compiler, which translates an entire high-level program into machine language, all at one time.

K: Strictly speaking, 'K' means exactly 1024 bytes (1024 is 2 to the tenth power). But 'K' is loosely used to mean 1000 bytes. So for instance, "32K" would mean 32 thousand bytes.

KERNAL: This is a set of machine language routines which perform fundamental tasks, such as controlling the position of the cursor, updating the internal clock (locations 160 - 162), and interrupting your program when you press STOP-RESTORE.

MACHINE LANGUAGE: An extremely primitive language of 1's and 0's which fundamentally is the only language which the computer can understand. Before the computer can process commands in other languages (such as BASIC), the commands must first be translated into machine language.

MEMORY: Usually refers to 'addressable memory' -- the memory which may be accessed with the PEEK and POKE commands. Altogether, there is 64K - 84K of this kind of memory, depending on exactly how you define the word 'addressable'. Sometimes 'memory` is used more broadly to include all components of the computer system which can "remember" information. This would include, for instance, the disk drives, and the registers in the 6510 microprocessor.

MICROPROCESSOR: A 'computer on a chip'. A microprocessor is an entire computer, stripped to its bare essentials, and compressed onto a single chip. A microprocessor typically has very little memory, and no

peripherals such as a screen or keyboard.

MICROSECOND: One millionth of a second. The fastest machine language commands are executed in somewhat less than a microsecond.

MILLISECOND: One thousandth of a second.

NANOSECOND: One billionth of a second. 1000 nanoseconds equals one microsecond.

OCTAL: Base 8. In Octal, the numbers from 0 to 20 are: 0, 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24.

OPERATING SYSTEM: A set of routines or programs which guide a computer through fundamental activities, such as displaying information on the screen, starting and stopping the motors in the disk drives, and displaying error messages. BASIC and the KERNAL are major parts of the COMMODORE-64 operating system.

PERIPHERAL: An add-on to your computer system, such as a screen, disk drive, printer, joystick, and so on.

POINTER: A piece of information in memory or on disk, which designates another location in memory or on disk. By means of pointers, information may cross-reference other pieces of information.

RAM (RANDOM ACCESS MEMORY): High-speed electronic memory, used chiefly to hold programs and routines currently being executed, and to act as a temporary storage area for small amounts of information. When the computer is turned off, all of the information in RAM is lost.

RECORD: In the case of an inventory file, a record would be the set of information on one item in inventory. The entire file would consist of a large number of records with the same information - format. In the case of a mailing list file, a record would be the name and address information on one person. The entire file would consist of a large number of records like this.

REGISTER: A small memory area on a microprocessor. The storage capacity of each register in the 6510

microprocessor is one byte (eight bits). Most microprocessors have no more than one or two dozen registers. Registers are used by a microprocessor primarily as tiny "scratch pads", to help them in doing their work.

ROM (READ ONLY MEMORY): Like RAM, except that information is permanently "burned in" to it. This information cannot be altered, and when the computer is turned off, the information remains in the ROM. The IBM PC is equipped with RAM which holds many of the routines for the operating system and for executing BASIC.

ROUTINE: A series of commands, written in a programming language (machine language, BASIC, FORTRAN) which performs some meaningful task.

SPECIAL KEYS: These are the SHIFT, CTRL, Commodore, and other special purpose keys which increase the power and versatility of your keyboard.

STORAGE: Usually refers to disk storage or cassette storage. Sometimes is used to mean other kinds of memory as well.

VARIABLE TYPES: In Commodore BASIC, there are three variable types: floating point (holds integer and decimal values); integer (holds integer values only); and string (used for all kinds of information).

INDEX

A-B

ARRAYS 92
ASCII 54-55, 73-75, 101-102
BANKS 60-62, 96
BASE TWO 44-45
BASIC KEYWORDS 73
BINARY 44-45, 69, 154, 157, 159
BOOT 2
BOX 145
BYTE 5

C-D

CASSETTE RECORDER 107-109
CHARACTER 145-146
CHARACTER ROM 166
CIA COMPLEX ADAPTOR 169
CIRCLE 143-144
CLOCK 34
COLOR 14 139
COLOR CODES 140
COLOR REGISTERS 140

D-G

DATA BLOCKS 104
DISK DRIVES 117-118
DISK FILES 121
DISK MAPS 118-119
DISKS 107-121
DRAW 144
ENVELOPE 134-135
GOSUB 58
GRAPHICS 139-149, 141

I-M

INPUT/OUTPUT 167
KERNAL 66
KEYBOARD 28-30
KILOBYTES 58
LIGHT PEN 148
MACHINE LANGUAGE 151-162
MEMORY 41-42, 51-56, 57, 63, 71-72
MEMORY 5 9
MICROPROCESSOR 163-165, 169
MONITOR 65

O-R

OPCODES 153-158
PEEK 11, 62
PERIPHERALS 64
PLAY 135-136
PLOTTING 142-143
POINTERS 58, 79, 81-89, 104, 172
POKE 13, 15, 16
RAM 59, 63, 65, 166
REFERENCE 172-173
REGISTER 155
ROM 60, 65, 166

S-T

SCALING 146-147
SCREEN MEMORY 8, 63, 68, 140-141
SEQUENTIAL FILES 110-116
SHAPE TABLE 35-39, 41-43, 46-47

SID CHIP 123-124
SOUND 32-34, 123-
137
SPECIAL KEYS 25
SPRITE 147-148

T-Z

TEMPO 134
VARIABLES 65, 91-93,
95-99, 105
VIC II CHIP 168
VOLUME 134
WINDOWS 148-149

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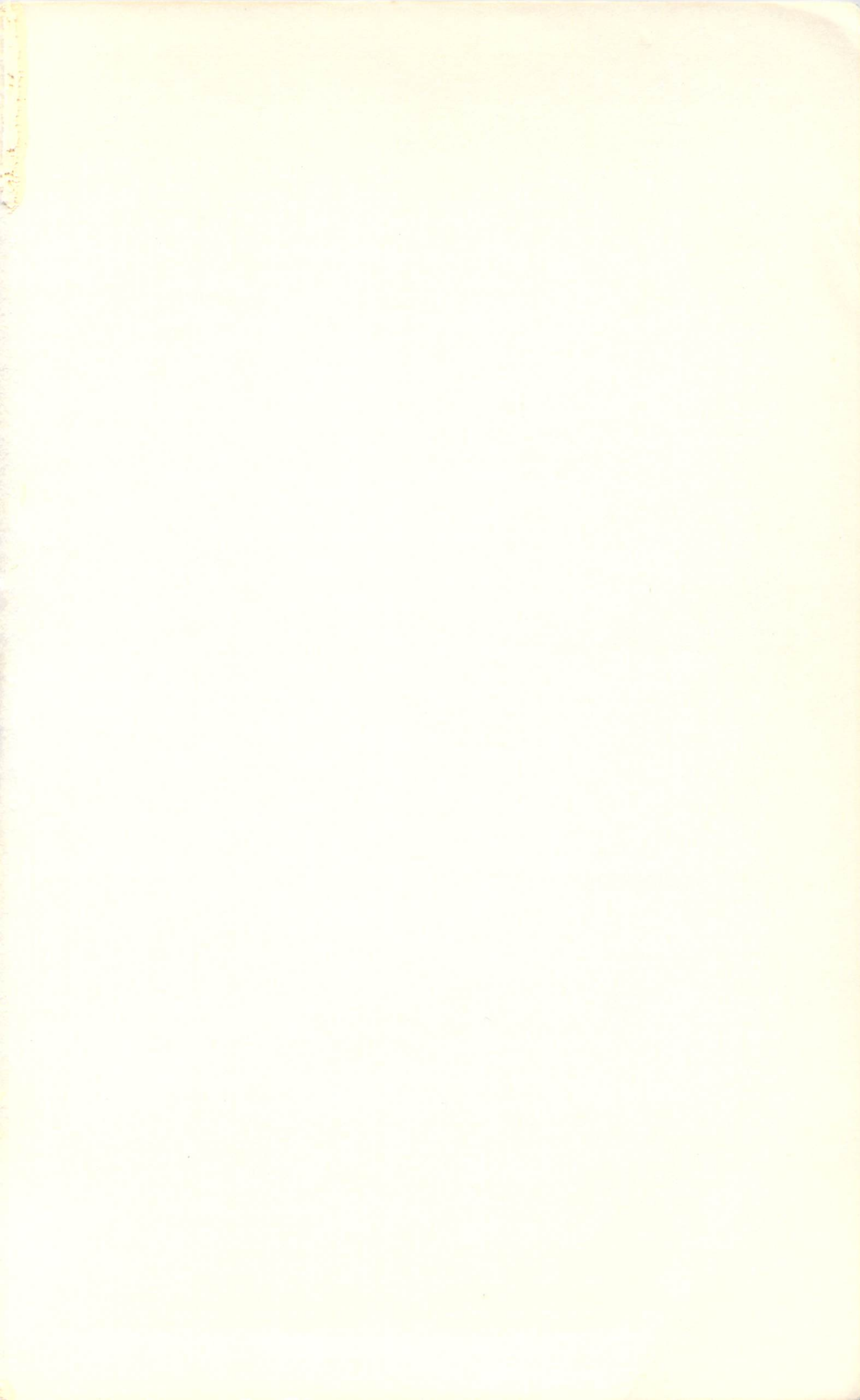

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