EVERYDAY WITH PRACTICAL ELECTRONICS

SEPTEMBER 1993

INCORPORATING ELECTRONICS MONTHLY

FULLY S.O.R. £1.80

LIGHTWORK
Check trailer lights without assistance

SOUND ACTIVATED TRIGGER
Tell your camera to take your picture

RAPID NICAD CHARGER
A 15 minute charge

CONSUMER ELECTRONICS SHOW-CHICAGO
The latest high tech. products reviewed by Barry Fox

PLUS: Circuit Surgery; Amateur Radio; Interface; New Technology; etc.

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THE No. 1 INDEPENDENT MAGAZINE for ELECTRONICS, TECHNOLOGY and COMPUTER PROJECTS

LAST MONTHS OFFERS

AMSTRAD MP3 £19.00

VHF/UHF TV Receiver, converts RGB or composite monitor into colour TV. Brand new and cased.

Our Price: £19.00
Our Ref :EV19P1

INDUCTIVE AMPS £5.00

Made for amplifying a telephone handset for the hard of hearing. However if you hold one against a piece of wire carrying a telephone conversation you can hear both sides of the conversation! It can also be used for tracing live wires in a wall or detecting cables carrying mains etc.
Fully cased complete with battery and fixing strap.
Aprox 2.5" diameter 1" thick.

Our Price:£5.00
Our Ref :EV5P1

CORDLESS PHONES (non working) £30.00 for 3

These are BT Curlews. They are not new and have been stored in sunlight so the plastic cases are discoloured. They also have the hanset aerial missing. This is a standard telescopic aerial - a piece of wire will do!
These are NON RETURNABLE!!

Our Price: £30.00 for 3
Our Ref :EV30P1

DISC DRIVES BBC MOD £9.00

JVC 3.5" drive supplied with well explained modification details to enable use with a BBC computer. Price includes drive and data.

Our Price: £9.00
Our Ref :EV9P1

RABBIT VIDEO SYSTEM £29.00

Enables video/audio signal to be received on any TV in the house. Use VCR remote with any TV (even non-remote) to control VCR functions dowstairs etc. Transmits via 2 wire system. Retails at £60.00.

Our Price: £29.00
Our Ref : EV29P1

CTM644 COLOUR MONITOR £79

Refurbished monitor suitable for many home computers standard RGB input.

Our Price: £79.00
Our Ref : EV79P1

MINIMUM GOODS ORDER £5.00. TRADE ORDERS FROM GOVERNMENT, SCHOOLS, UNIVERSITIES & LOCAL AUTHORITIES WELCOME. ALL GOODS SUPPLIED SUBJECT TO OUR CONDITIONS OF SALE AND UNLESS OTHERWISE STATED GUARANTEED FOR 30 DAYS.
RIGHTS RESERVED TO CHANGE PRICES & SPECIFICATIONS WITHOUT PRIOR NOTICE. ORDERS SUBJECT TO STOCK. QUOTATIONS WILLINGLY GIVEN FOR QUANTITIES HIGHER THAN THOSE STATED.

THIS MONTHS BIG OFFERS

100W DOOR/SHELF SPEAKERS

Hi-fi quality 3-way co-axial flush mounting speaker system. Unique design gunmetal and blackgrille. 100W max. power handling per speaker. Frequency repsonce -=60-200000Hz
Speaker size =6.5"woofer, 2"mid, 1"tweeter
Impedance = 4 Ohm
Mounting Depth -=39mm

OurSpecial Price: £23.99
Our Ref : EV24P1

3 BUTTON LOGITECH MOUSE

Originally made for the Acorn Archimedies but could be easily adapted for other machines. Pin details are supplied. NO SOFTWARE.

Our Price: £4.99
Our Ref : EV5P2

5 VOLT 4.4 AMP PSU

Acompact switch mode PSU with on/off switch, selectablevoltage input 110/240. NEW. O/P via fly leads. GOOD STOCKS AVAILABLE

Our Price : £4.99
Our Ref : EV5P3

XENON STROBE (ALARM BEACON)

12V stobe, clear lens, ideal for alarm box idicator or in multiples as a display array. Great for special effects and other leisure applications. Could be used as a vehicle tamper indicator.

Our Price: £5.00
Our Ref :EV5P4

AA NICADS AND CHARGER PCB

150x80mm board includes 5 x AA, fast and tricklecharge facility change over relay, connector strip.
NO CONECTION DETAILS.

Our Price :£2.99
Our Ref : EV3P1

PIR MOVEMENT DETECTOR

Once again we have aquired stocks of this popular line and are able to offer you a very high quality and professional detector at only **£15.00**. Range: 20 Mtrs with a 90 arc. Day and Night mode. Diamensions: 15cm x 9cm x 11cm. New and boxed complete with installation guide.

Our Price: £15.00
Our Ref :EV15P1

ACORN ELECTRON AC PSU

19V AC 14W very easily adaptable simply add a small bridge rectifier, 3 pin plug in.

Our Price: £2.99 each
Our Ref :EV3P2

SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

BULL ELECTRICAL

250 PORTLAND ROAD HOVE SUSSEX
BN3 5QT

MAIL ORDER TERMS: CASH PO OR CHEQUE WITH ORDER PLUS £3.00 POST PLUS VAT.
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FAX: 0273 323077

VISA

THIS AUTUMNS FASTEST GROWING MEDIA!

CD ROM DRIVE

The Mitsumi CD ROM DRIVE will realise the true potential of your computer. Once installed through Microsoft Windows 3.1 over 500Mbyte of data can be stored on a single disk, but it is a read only medium. A vast library of CD ROM disks are available from a huge numbers of suppliers and titles include whole encyclopedias. This unit can also reproduce HiFi quality music CDs and delivers high resolution digital pictures. The Mitsumi drive is Kodak CD compatible enabling you to transfer 35mm film onto a CD, a process undertaken in the chemist or with a Kodak CD lab. View your holiday photos on your computer monitor using the ROM DRIVE.

OUR PRICE: £169.00
OUR REF : EV169P1

We also stock the following titles at **£29.00 each:**
Wing commander **REF:EV29P1,**
Guinness Disk of Records **REF:EV29P2**
World Atlas **REF:EV29P3**
and Sherlock Holmes **REF:EV29P4**

MANY MORE SPECIAL OFFERS IN OUR REGULAR NEWSLETTERS

WE HAVE HUNDREDS AND HUNDREDS MORE STOCK LINES - TOO MANY TO LIST IN ONE ADVERT CHOOSE FROM...

AERIAL AMPLIFIERS	FANS
AEROSOLS	FUSES
ALARMS	GLUEGUN AND GLUE
AMPLIFIED SPEAKERS	HEADPHONES
ANALOUGUE MULTIMETERS	HEATSHRINK SLEEVING
APPLIANCE LEADS	HI FI SPEAKERS
BATTERIES AND HOLDERS	IONISERS
BATTERY CHARGERS	LED's
BOOKS	LASERS AND LASER PSU's
BOXES AND CASES	LOGIC PROBES
CAMCORDER BITS	LOUD AND MARINE SPKRS
CAPACITORS	MICROPHONES
CAR AMPS, RADIOS & SPKRS	PIR LIGHTS AND DETECTOR
CB SPEAKERS AND PSU's	POWER SUPPLIES
COMPUTER BITS	POWER AMPLIFIERS
CONNECTORS	RADIOS
DESOLDER PUMP	SERVICE AIDS
DIGITAL MULTIMETERS	SOLDERING EQUIPMENT
DISCO LIGHTING	STEAM ENGINES
DISPLAYS	TRANSEIVERS
DUBBING KIT	TRANSFORMERS
DRILLS	WIRELESS MICROPHONES

IN SUSSEX?
CALL IN AND SEE US!!

TURN YOUR SURPLUS STOCK INTO CASH. IMMEDIATE SETTLEMENT. WE WILL ALSO QUOTE FOR COMPLETE FACTORY CLEARANCE.

MUCH MUCH MORE IN OUR 1993 CATALOGUE. PLEASE SEND 41P. A4 SIZED SAE FOR YOUR FREE COPY.

VOL. 22 No. 9 SEPTEMBER 1993

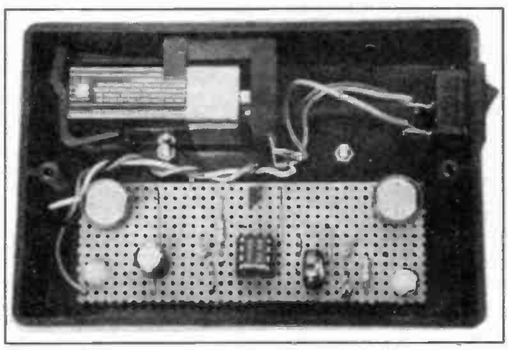
EVERYDAY WITH PRACTICAL ELECTRONICS

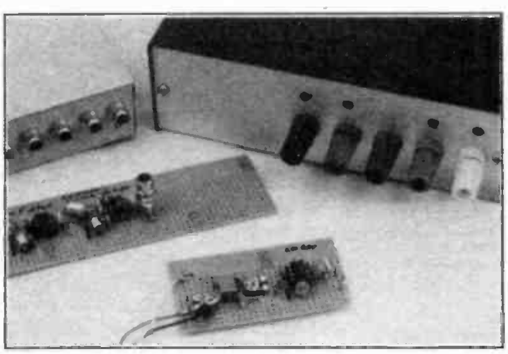
INCORPORATING ELECTRONICS MONTHLY

The No. 1 Independent Magazine for Electronics, Technology and Computer Projects

ISSN 0262 3617

PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .





Our October '93 issue will be published on Friday, 3 September 1993. See page 635 for details.

Projects

Series

Features

NEXT MONTH

FREE

NEW BUMPER MARCO 1994 CATALOGUE

worth £2

MULTI-PURPOSE AUDIO SYSTEM

This short series of articles features a number of audio modules which enable the constructor to produce a tailor made system. All the modules will operate alone, but are compatible with each other. The modules include:

- *Module 1. Stereo Mixer (6-channel, low noise)*
- *Module 2. RIAA Stereo Pre-amp (for record decks)*
- *Module 3. Microphone Pre-amp*
- *Module 4. Bass/Treble/Volume/Balance Control*
- *Module 5. 1 watt per channel Stereo Amplifier*
- *Module 6. 10 Watt per channel Stereo Amplifier*

The main mixer p.c.b. includes two Module 2s and two Module 3s. Separate p.c.b. layouts for Modules 2 and 3 are also provided.

The facilities available on each unit are quite extensive so if you want to set up a home recording system, mix sound for videos, run a disco or a small band then this series should provide the system you require.

KETTLE ALERT

Modern kettles are helpful because they turn themselves off when the water has boiled. But how often have you forgotten you had turned the kettle on, only to come back minutes later and wait for it to boil again. It was never a problem with an old fashioned whistling kettle and our Kettle Alert restores this function.

Neatly housed in an oversized mains plug the unit will sound when the kettle switches off. It is mains powered and quite simple to build – you'll wonder what you ever did without it.

BECOMING A RADIO AMATEUR

It's a fascinating hobby but one that tends to be shrouded with jargon and technical terms. We cut through the mist and give a straightwforward explanation of just how easy it is to get involved with amateur radio. The article looks at everything from listening, to types of licence and the Radio Amateur Examination (RAE). If you want to become a HAM, or just listen in, then this article is for you.

EVERYDAY WITH PRACTICAL ELECTRONICS

OCTOBER ISSUE ON SALE FRIDAY, SEPTEMBER 3rd

HART AUDIO KITS – YOUR VALUE FOR MONEY ROUTE TO ULTIMATE HI-FI

HART KITS give you the opportunity to build the very best engineered hifi equipment there is, designed by the leaders in their field, using the best components that are available.
Every HART KIT is not just a new equipment acquisition but a valuable investment in knowledge, giving you guided hands-on experience of modern electronic techniques.
In short HART is your 'friend in the trade' giving you, as a knowledgeable constructor, access to better equipment at lower prices than the man in the street.
You can buy the reprints and construction manual for any kit to see how easy it is to build your own equipment the HART way. The FULL cost can be credited against your subsequent kit purchase.
Our list will give you fuller details of all our Audio Kits, components and special offers.

AUDIO DESIGN 80 WATT POWER AMPLIFIER.

This fantastic John Linsley Hood designed amplifier is the flagship of our range, and the ideal powerhouse for your ultimate hifi system. This kit is your way to get £K performance for a few tenths of the cost!. Featured on the front cover of 'Electronics Today International' this complete stereo power amplifier offers World Class performance allied to the famous HART quality and ease of construction. John Linsley Hood's comments on seeing a complete unit were enthusiastic:- "The external view is that of a thoroughly professional piece of audio gear, neat elegant and functional. This impression is greatly reinforced by the internal appearance, which is redolent of quality, both in components and in layout." Options include a stereo LED power meter and a versatile passive front end giving switched inputs using ALPS precision, low-noise volume and balance controls. A new relay switched front end option also gives a tape input and output facility so that for use with tuners, tape and CD players, or indeed any other 'flat' inputs the power amplifier may be used on its own, without the need for any external signal handling stages. 'Slave' and 'monobloc' versions without the passive input stage and power meter are also available. All versions fit within our standard 420 x 260 x 75mm case to match our 400 Series Tuner range. ALL six power supply rails are fully stabilised, and the complete power supply, using a toroidal transformer, is contained within a heavy gauge aluminium chassis/heatsink fitted with IEC mains input and output sockets. All the circuitry is on professional grade printed circuit boards with roller tinned finish and green solder resist on the component ident side, the power amplifiers feature an advanced double sided layout for maximum performance. All wiring in this kit is pre-terminated, ready for instant use!

RLH11 Reprints of latest articles.....................£1.80
K1100CM HART Construction Manual.............£5.50

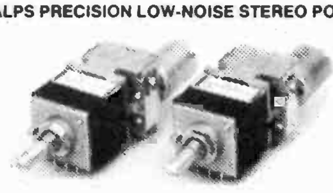
LINSLEY HOOD 1400 SERIES ULTRA HIGH-QUALITY PREAMP

Joining our magnificent 80 Watt power amplifier now is the most advanced preamplifier ever offered on the kit, or indeed made-up marketplace. Facilities include separate tape signal selection to enable you to listen to one programme while recording another, up to 7 inputs, cross recording facilities, class A headphone amplifier, cancellable 3-level tone controls and many other useful functions, all selected by high quality relays. For full details see our list.

LINSLEY HOOD 'SHUNT FEEDBACK' R.I.A.A. MOVING COIL & MOVING MAGNET PICKUP PREAMPLIFIERS

Modern, ultimate sound systems are evolving towards built-in preamplifiers within or near the turntable unit. This keeps noise pickup and treble loss to a minimum. We now offer two units, both having the sonically preferred shunt feedback configuration to give an accurate and musical sound, and both having the ability to use both moving magnet and moving coil cartridges.
Kit K1500 uses modern integrated circuits to achieve outstanding sound quality at minimal cost. The very low power requirements enable this unit to be operated from dry batteries and the kit comes with very detailed instructions making it ideal for the beginner. K1500 Complete kit with all components, printed circuit board, full instructions and fully finished case...£67.99
Instructions only...£2.80
Kit K1450 is a fully discrete component implementation of the shunt feedback concept and used with the right cartridge offers the discerning user the ultimate in sound quality from vinyl disks. Can be fitted inside our 1400 Preamp, used externally or as a standalone unit. It has a higher power requirement and needs to be powered from our 1400 Series preamplifier or its own dedicated power supply.
K1450 Complete Discrete Component RIAA Phono Preamp..£109.58
Factory Assembled and Tested.....................£159.58
K1565 Matching Audio Grade Power Supply with potted toroidal transformer and limited shift earthing system...£79.42
Factory Assembled and Tested.....................£118.42
U1115 Power Interconnect Cable.....................£7.29

ALPS PRECISION LOW-NOISE STEREO POTS



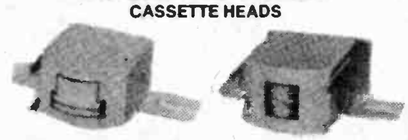
Super Savings with our "3 for the price of 2" Offer.
Now back in stock our range of the fabulous ALPS range of High Grade Audio Pots fulfill the need for no compromise quality controls as used in HART Kits and other World Class Amplifiers. This exciting range covers the values needed for most quality amplifier applications.
Now you can throw out those noisy ill-matched carbon pots and replace with the real hi-fi components. The improvement in track accuracy and matching really is incredible giving better tonal balance between channels and rock solid image stability.
All pots are 2-gang stereo format, with 20mm long 6mm diam. steel shafts. Overall size of the manual pot is 27mm wide x 24mm high x 27mm deep, motorised versions are 72.4mm deep from the mounting face. Mounting bush for both types is 8mm diameter. Motorized versions have 5V d.c. drive motor.

MANUAL POTENTIOMETERS
2-Gang 100K Lin. £15.67
2-Gang 10K, 50K or 100K Log. £16.40
2-Gang 10K Special Balance, zero crosstalk and zero centre loss...£17.48
MOTORISED POTENTIOMETERS
2-Gang 20K Log Volume Control.....................£26.20
2-Gang 10K RD Special Balance, zero crosstalk and less than 10% loss in centre position..............£26.98
OUR SPECIAL OFFER ON ALPS POTS. Buy any two and get the third FREE. (The third must be the same or a cheaper type).

STUART REEL-TO-REEL TAPE RECORDER CIRCUITS

Complete stereo record, replay and bias circuit system for reel-to-reel recorders. These circuits will give studio quality with a good tape deck. Separate sections for record and replay give optimum performance and allows a third head monitoring system to be used where the deck has this fitted. Standard 250mV input and output levels. Ideal for bringing that old valve tape recorder back to life. Suitable stereo heads are in our head list. This basic kit is suitable for advanced constructors only.K900W Stereo Kit with Wound Coils and Twin Meter Drive...£123.93
RJS1 Reprints of Original Descriptive Articles..£3.60

HIGH QUALITY REPLACEMENT CASSETTE HEADS



Do your tapes lack treble? A worn head could be the problem. For top performance cassette recorder heads should be replaced every 1,500 hours. Fitting one of our high quality replacement heads could restore performance to better than new!. Standard inductances and mountings make fitting easy on nearly all machines (Sony are special dimensions, we do not stock) and our TC1 Test Cassette helps you set the azimuth spot on. As we are the actual importers you get prime parts at lower prices, compare our prices with other suppliers and see! All our heads are suitable for use with any Dolby system and are normally available ex stock. We also stock a wide range of special heads for home construction and industrial users.
HC80 NEW RANGE High Beta Permalloy Stereo head. Modern space saver design for easy fitting and lower cost. Suitable for chrome metal and ferric tapes, truly a universal replacement head for everything from hi-fi decks to car players and at an incredible price too!...£8.30
HRP373 Downstream Monitor
Stereo Combination Head.............................£53.90
HQ551A 4-Track Record/Play Head £8.75
HM120 Standard Mono R/P Head.....................£3.44
H524 Standard Erase Head..............................£1.90
H561 Hi Field Erase Head for METAL Tapes......£3.49
SM150 2/2 (Double Mono) DC Erase Head.........£5.20
HQ751E 4/4 True 4-Track Erase Head..............£57.06

REEL TO REEL HEADS

999R 2/4 Record/Play 110mH. Suits Stuart Tape Circuits...£13.34
998E 2/4 Erase Head 1mH. Universal Mount. Suits Stuart...£11.96

"Full spec., treble D Quality Classical and Opera Compact Disks at incredible prices. Send for full list of titles."

HART TC1D *Triple Purpose* TEST CASSETTE

Now available again and even better than before! Our famous triple purpose test cassette will help you set up your recorder for peak performance after fitting a new record/play head. This quality precision Test Cassette is digitally mastered in real time to give you an accurate standard to set the head azimuth, Dolby/VU level and tape speed, all easily done without test equipment.
TC1D Triple Purpose Test Cassette £14.99

TAPE RECORDER CARE PRODUCTS

DEM1 Mains Powered Tape Head Demagnetizer, prevents noise on playback due to residual head magnetisation.................£4.08
DEM115 Electronic, Cassette Type, demagnetizer...£8.61

Send or 'phone for your copy of our List (50p) of these and many other Kits & Components. Enquiries from Overseas customers are equally welcome, but PLEASE send 2 IRCs if you want a list sent surface post, or 5 for Airmail.
Ordering is easy. Just write or telephone your requirements to sample the friendly and efficient HART service. Payment by cheque, cash or credit card. A telephoned order with your credit card number will get your order on its way to you THAT DAY.
Please add part cost of carriage and insurance as follows:–**INLAND Orders up to £20 - £1.50, Orders over £20 - £3.50. Express Courier, next working day £10.**
OVERSEAS – Please see the ordering information with our lists.

QUALITY AUDIO KITS	24 hr. SALES LINE (0691) 652894	ALL PRICES INCLUDE UK/EC VAT

HART ELECTRONIC KITS LTD
6 PENYLAN MILL
OSWESTRY, SHROPSHIRE
SY10 9AF

MOTORS – BATTERY 1-12V

3 Different model motors, £1, Order Ref. 35.
Spin to start 3V d.c. motors for model aircraft etc., 5 for £1, Order Ref. 134.
Cassette motor 1.5V-12V, powerful, speed increases with voltage, £1, Order Ref. 224.
1½V High efficiency motor for solar cell working, £1, Order Ref. 643.
12V motor ex BSR record player, £1, Order Ref. 687.
9V cassette motor, brushless, £1.50, Order Ref. 1.5P14.
1/10hp 12V d.c. motor Smiths, £4, Order Ref. 4P22.
1/8hp 12V motor, Smiths, £6, Order Ref. 6P1.
1/6hp 12V motor, Smiths, £8, Order Ref. 8P14.
1/3hp motor (Sinclair C5), £15, Order Ref. 15P8.

MAINS MOTORS WITH GEARBOXES

5rpm 60W, £5, Order Ref. 5P54.
40rpm 100W, £6, Order Ref. 6P21.
50rpm 60W, £5, Order Ref. 5P168.
60rpm 60W, £5, Order Ref. 5P171.
110rpm 60W, £5, Order Ref. 5P172.
150rpm 60W, £5, Order Ref. 5P169.
500W motor with gearbox & variable speed selector, 100rpm upwards, £3, Order Ref. 3P8.
1 rev per 24 hours 2W motor, £1, Order Ref. 89.
1 rev per 12 hours 2W motor, £1, Order Ref. 90.
1 rev per 4 hours 2W motor, £2, Order Ref. 2P239.
1 rev per hour 2W extra small motor, 2 for £1, Order Ref. 500.
½ rpm miniature motor, £3, Order Ref. 3P64.
4 rpm 2W motor, £1, Order Ref. 446.
15rpm 2W motor, £2, Order Ref. 2P321.
25rpm 2W motor, £2, Order Ref. 2P322.
200rpm 2W motor, £1, Order Ref. 175.
250rpm 2W motor, £1, Order Ref. 750.

MAINS MOTORS

¾ stack motor with ¼" spindle, £1, Order Ref. 85.
Motor 1½" stack with good length spindle from each side, £2, Order Ref. 2P55.
Shaded pole motor with 4" long spindle, £2, Order Ref. 2P203.
Motor by Crompton .06hp but little soiled, £3, Order Ref. 3P4.
Jap made precision motor balanced rotor 1500rpm, £2, Order Ref. 2P12.

MOTOR – STEPPER

Mini motor 12V – 7.5 degree step, £1, Order Ref. 910.
Motor by Eastern Air Devices, £2, Order Ref. 2P266.
Very powerful motor by American Philips 10-14V 7.5 degree step, £5, Order Ref. 5P81.
Tape motor by EMI 2 speed & reversible, £2, Order Ref. 2P70.

LOUDSPEAKERS

2" round 50 ohm coil ⅓W, 2 for £1, Order Ref. 908.
2 ¼" 8 ohm, 2 for £1, Order Ref. 454.
2½" 35 ohm, 2 for £1, Order Ref. 514.
3½" 8 ohm, 2 for £1, Order Ref. 682.
6½" 4 ohm, with tweeter, £1, Order Ref. 895.
6½" 6 ohm, £1, Order Ref. 896.
6½" 8 ohm, with tweeter, £1, Order Ref. 897.
6" x 4" 4 ohm, £1, Order Ref. 242.
5" x 5" 15 ohm, £1, Order Ref. 906.
5" x 3" 16 ohm, £1, Order Ref. 725.
7" x 4" 16 ohm, 2 for £1, Order Ref. 684.
8" 15 ohm audax, £1, Order Ref. 504.
9" x 3" 8 ohm, 5W, £1, Order Ref. 138.
9" x 4" 4 ohm, £1, Order Ref. 935.
3" 4 ohm, tweeter, £1, Order Ref. 433.
Goodmans 6½" 10W 4 ohm, £2, Order Ref. 2P27.
6" x 4" 15 ohm 10W, £2, Order Ref. 2P167.
Horn speaker, £3, Order Ref. 3P82.
20W 5" by Goodmans, £3, Order Ref. 3P145.
20W 4 ohm tweeter, £1.50, Order Ref. 1.5P9.
40W 6½" round, 8 ohm, with built-in tweeter, £4.50, Order Ref. 4.5P5.
Amstrad 8" 15W 8 ohm with matching tweeter, £4, Order Ref. 4P57.
Cased pair of stereo speakers by Bush 4 ohms **£5** per pair, Order Ref. 5P141.
Double wound voice coil 25W, ITT, **£7,** Order Ref. 7P12.
Bulkhead speaker, metal cased, **£10,** Order Ref. 1043.
25W 2 way crossover, 2 for £1, Order Ref. 22.
40W 3 way crossover, £1, Order Ref. 23.

MONITORS AND BITS

Philips 9 " high resolution monitor, **£15,** Order Ref. 15P1.
Metal case for the above Philips monitor, **£12,** Order Ref. 12P3.
Philips 9" high resolution tube ref. M24 306W, **£12,** Order Ref. 12P7.
Electrostatic monitor tube ref. SE5J31, **£15,** Order Ref. 15P4.
Mini scope tube mu metal ex unused monitors, face size approx. 2" x 2½", £10, Order Ref. 10P73.

SOME POPULAR BARGAINS

AMSTRAD 3" DISK DRIVE. Brand new. Standard replacement or why not have an extra one? £20, Order Ref. 20P28.
THIS COULD SAVE YOU EXPENSIVE BATTERIES an in-car unit for operating 6V radio, cassette player, etc from car lighter socket, £2, Order Ref. 2P318.
FULLY ENCLOSED MAINS TRANSFORMER on a 2m 3 core lead terminating with a 13A plug. Secondary rated at 6V 4A. Brought out on a well insulated 2 core lead terminating with insulated push on tags. £3, Order Ref. 3P152. Ditto but 8A, £4, Order Ref. 4P69.
STOP THOSE PEAKS as they come through the mains, they can damage your equipment. 2A unit is a combination of cores and caps, gives complete protection. £2, Order Ref. 2P315.
DIGITAL MULTI TESTER M3800 single switching covers 30 ranges including 20A a.c. and d.c. 10meg input impedence, 3½ LCD display. Complete with lead. Currently advertised by many dealers at nearly £40, our price only £25, Order Ref. 25P14.
ANALOGUE TESTER. Input impedence 2K ohms per volt. It has 14 ranges, a.c. volts 0-500 d.c. volts 0-500, d.c. current 500 micro amps at 250 milliamp, resistance 0-1 meg-ohm, decibels 20 ± 56 dB. Fitted diode protection, overall size 90 x 60 x 30mm. Complete with test prods, price £7.50, Order Ref. 7.5P8.
LCD CLOCK MODULE. 1.5V battery operated, fits nicely into our 50p project box, Order Ref. 876. Only £2, Order Ref. 2P307.
SENTINEL COMPONENT BOARD amongst hundreds of other parts, this has 15 ICs all plug in so don't need de-soldering. Cost well over £100, yours for £4, Order Ref. 4P67.
AMSTRAD KEYBOARD MODEL KB5. This is a most comprehensive keyboard, having over 100 keys including, of course, full numerical and qwerty. Brand new, still in maker's packing, £5, Order Ref. 5P202.
FM CORDLESS RADIO MIKE hand held, battery operated model. Very good performer and really professional looking, has usual shaped body and head and is tuneable to transmit and be picked up on the FM band of any radio. Yours for only £8.50, Order Ref. 8.5P1.
ULTRA SONIC TRANSDUCERS 2 metal cased units, one transmits, one receives. Built to operate around 40kHz. £1.50 the pair, Order Ref. 1.5P4.
INSULATION TESTER WITH MULTIMETER internally generates voltages which enables you to read insulation directly in megohms. The multimeter has 4 ranges a.c./d.c. volts, 3 ranges d.c. milliamps, 3 ranges resistance and 5 amps. These instruments are ex BT but in very good condition, tested and guaranteed OK, yours for only £7.50, with leads, carrying case £2 extra, Order Ref. 7.5P4.
MAINS ISOLATION TRANSFORMER stops you getting "to earth shocks". 230V in and 230V out. 150W upright mounting, £7.50, Order Ref. 7.5P5 and a 250W version is £10, Order Ref. 10P79.
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EVERYDAY WITH PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

VOL. 22 No. 9 SEPTEMBER '93

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MATHS, MATHS, MATHS

More maths, no maths, how much maths? Quite often we find readers who say things like "I don't understand how you work this out" or "I don't want to know all the figures just tell me what the value should be". These opposing requests leave us in a bit of a quandry. Do we forget all the maths which go behind every electronic design? Do we get the point across with a minimum of maths, or do we explain everything with formulae, etc., for those who can understand it all?

We usually take the view that those who understand all the maths are probably aware of the required calculations and those who don't will only want to see a minimum amount. However, there are those who would like to be able to work things out, but find they don't know how. (If you are with me so far, great, because I am coming to the point quite soon.)

DECISIONS, DECISIONS

So how do we decide how much maths to carry in the magazine: will too much put off those who don't want it, or don't understand it? What we want is for you to tell us and, just to help you decide, we have included an article called *Working It Out* in this issue. This contains some simple guide lines on making approximate calculations; it is not full of formulae nor does it try to teach you maths or how to use a calculator. What it will do, however, is give you a feel for dealing with simple maths involved in electronics and how to "cheat" a little to get an approximate answer.

If you do find the maths interesting and would like to see more, let us know, we have a series available, with the working title of *Calculation Corner*, which looks at the maths behind electronics and we are not sure if this would go down well or not. Let us have your views one way or the other – you really can influence the content of EPE.

Mike Kenward

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We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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Constructional Project

SOUND ACTIVATED CAMERA TRIGGER

ROBERT PENFOLD

No need to feel left out! – share the spotlight with family and friends. Create "special effects" – water splashes, breaking glass, etc.

MOST cameras nowadays have a self-timer facility which enables photographs to be taken about five to ten seconds after the release button has been activated. This facility is included primarily to enable the photographer to take self portraits.

In many instances a simple self-timer facility is quite adequate, but the delay sometimes proves to be too short. In particular, it is often inadequate when the photographer has to position him or herself in a group of people. The delay can also be too short if the photographer wishes to pose with a prop, such as the one that did not get away, or some sort of cup or trophy.

SOUND DELAY

One solution to the problem is to use an add-on timer unit that gives a longer delay, and a mechanical unit of this type (for use with a conventional cable release socket) is produced. Another approach is to use a sound switch/delay unit to trigger the camera. The general idea is to get into position and then shout to activate the trigger unit. After a brief delay to allow the operator to compose him or herself, the camera is then automatically triggered.

The unit featured here is a sound activated camera switch and delay unit which is intended for use in the manner outlined above. It is designed to operate with an external microphone, and the output should be able to operate any camera which has an electronic release facility.

This includes many modern SLR cameras, plus some of those from about 10 to 20 years ago. Note though, that with some of these older cameras electronic triggering is only possible if the camera is fitted with some kind of motor drive or winder. Few compact cameras (ancient or modern) have an electronic release facility.

Obviously this project should not be built unless the prospective constructor definitely has a suitable camera for it to control, and a suitable lead to connect the trigger unit to the camera can be obtained. If in doubt, check with the camera manufacturer or their UK agent.

SYSTEM OPERATION

The system operation block diagram is shown in Fig. 1. The signal level from the microphone will normally be at a very low level (under one millivolt peak-to-peak). Two stages of amplification are therefore used at the input of the unit in order to boost the microphone signal to a more useful level.

A gain control is included between the

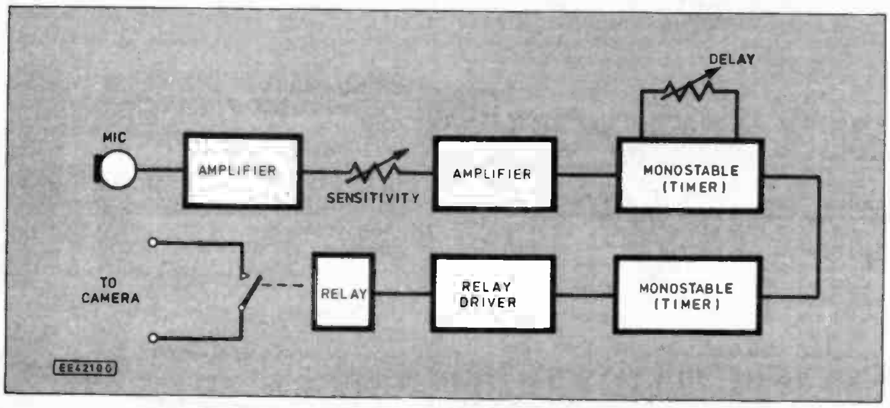


Fig. 1. The Sound Activated Camera Trigger block diagram.

COMPONENTS

Resistors

R1, R4	2M2 (2 off)
R2	2k2
R3	10k
R5	4k7
R6	1k
R7	1M
R8	1k5

All 0·25W 5% carbon film

See SHOP TALK Page

Potentiometer

VR1	10k rotary carbon, log.
VR2	100k rotary carbon, lin.

Capacitors

C1, C2	100μ radial elect. 10V (2 off)
C3, C6	1μ radial elect. 63V (2 off)
C4	1n polyester
C5	2μ2 radial elect. 63V
C7	22μ radial elect. 16V
C8	100n polyester

Semiconductors

D1	Red panel l.e.d.
D2	1N4148 silicon signal diode
TR1, TR2, TR3	BC549 *npn* silicon transistor (3 off)
IC1	NE555 timer
IC2	4047BE CMOS timer

Miscellaneous

JK1	3·5mm jack socket
S1, S2	Miniature s.p.s.t. toggle switch (2 off)
RLA	12V, 320 ohm coil, relay with s.p.d.t. contacts
B1	12V battery pack (eight HP7 cells in holder) – see text

Case about 150mm x 175mm x 50mm; printed circuit board available from *EPE PCB Service*, code 840; battery connector (PP3 type); control knob (2 off); lead etc. to make connections to camera (see text); 8-pin d.i.l. i.c. holder; 14-pin d.i.l. i.c. holder; wire; solder etc.

Approx cost guidance only **£15** *excl. batts* two amplifier stages, and this is effectively a "Sensitivity" control. It is advisable not to use too high a sensitivity than is really necessary as this would increase the risk of accidental triggering of the camera.

The output from the second amplifier is fed to the input of a monostable. This stage is triggered by suitably strong signals from the second amplifier, and it then provides and output pulse of variable duration. The pulse length can be set anywhere between about 25 milliseconds and 2·5 seconds.

The monostable sets the delay between the sound being made and the camera being triggered. For normal use the delay should be around one to 2·5 seconds. Shorter delays are useful if the unit is to be used for "trick" shots, such as water splashes, smashing light bulbs, etc. The delay can be switched out completely if desired.

Another monostable stage is triggered from the output of the first one. This monostable has an output pulse of fixed duration, and the pulse length is set at just under half a second. The length of this pulse is not critical, and it simply controls the time for which the camera's electronic release is operated.

The monostable controls the camera via a relay and a relay driver stage. A relay at pin 2 of IC1 is taken below one third of the supply voltage.

Normally the collector of TR2 is at about half the supply voltage, or a little higher, but with a suitably strong microphone signal it will go below one third of the supply potential on negative half cycles. The output at pin 3 of IC1 then goes high for a period that is determined by potentiometer VR2, fixed resistor R6, and electrolytic capacitor C7.

DELAY CONTROL

The Delay control VR2 permits the pulse length to be varied over the approximate time range mentioned previously. Switch S2 enables C7 to be switched out of circuit, which effectively removes the delay provided by IC1.

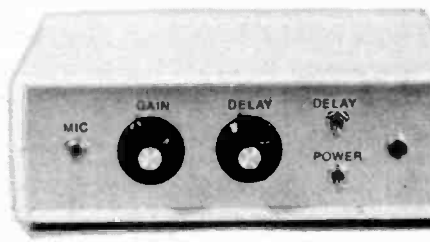
A CMOS 4047BE astable/monostable i.c. acts as the second monostable stage IC2. It is wired to operate as a negative edge triggered monostable. Consequently, it triggers as the positive output pulse from IC1 comes to an end, so that IC1 introduces the required delay. Resistor R7 and capacitor C8 set the output pulse duration from IC2 at just under half a second.

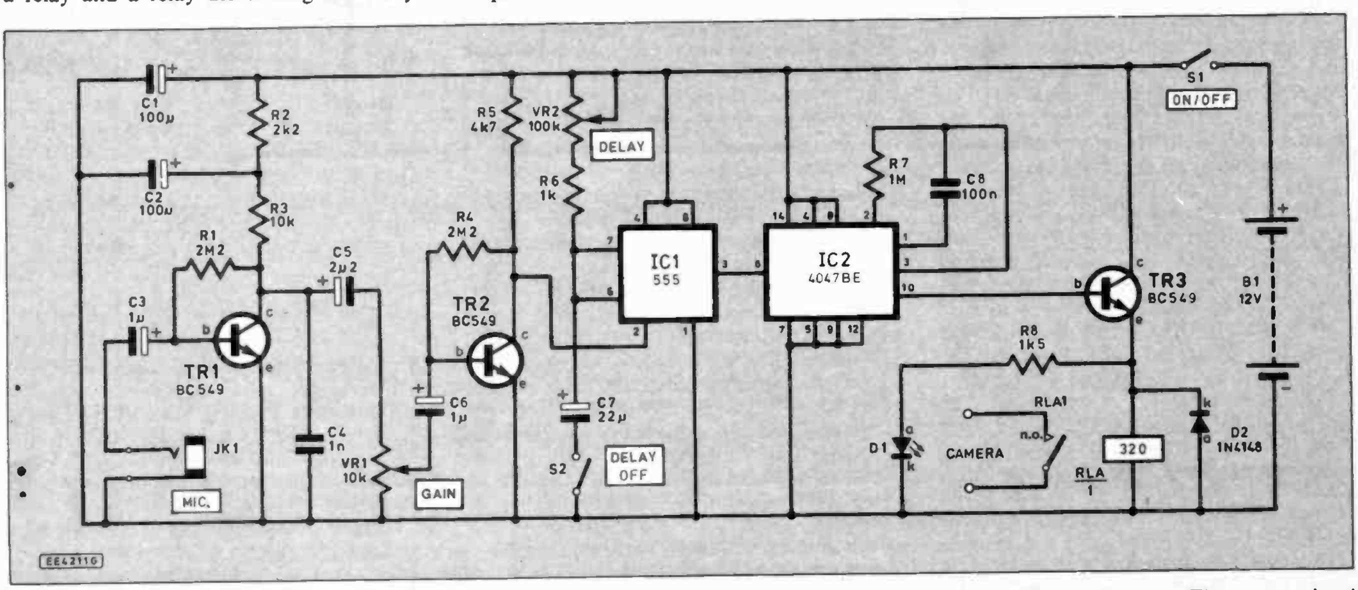
IC2 has complementary Q and not $\bar{Q}$ outputs. In this case it is only the Q output at pin 10 which is utilized. This drives the relay coil RLA via transistor TR3, which is a simple emitter follower buffer stage. Diode D2 suppresses any reverse high voltage spikes which might otherwise be generated across the highly inductive relay coil each time it is switched off.

The relay is basically just a mechanical switch which is operated by an electromagnet. The relay used here has a single set of changeover contacts, but in this application they are used as a set of normally open contacts (n.o.). The contacts close and operate the camera when the relay is switched on.

Diode D1 is a l.e.d. indicator which is activated while the relay is switched on. This is useful for "dummy" runs when setting up a shot, and can help to minimise wasted frames.

The circuit is powered from a 12 volt bat-





might seem to be an old fashioned method of controlling the camera, but the circuit that is being controlled is something of an "unknown quantity". The mechanical contacts of a relay should control any camera or motor drive properly, whereas semiconductor switching devices might fail to give satisfactory results.

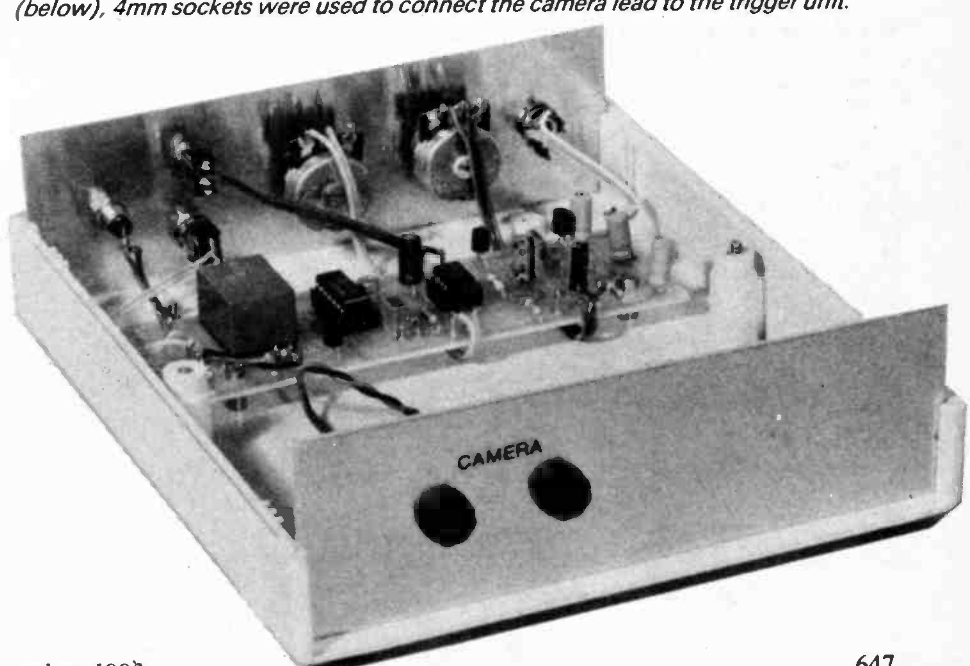
Fig. 2. Full circuit diagram for the Sound Activated Camera Trigger. The output lead arrangement will, of course, depend on the camera used. In the prototype model (below), 4mm sockets were used to connect the camera lead to the trigger unit.

CIRCUIT OPERATION

The full circuit diagram of the Sound Activated Camera Trigger unit is shown in Fig. 2. Transistor TR1 is used as the basis of the first amplifier stage, which is a high gain common emitter type. It provides a voltage gain of over 40dB (100 times).

The output of this stage is coupled to the Gain control (VR1), and from here the signal is coupled to the input of the second amplifier stage. This is based on transistor TR2, and it is another high gain common emitter type.

The output of TR2 is direct coupled to the input of the first monostable stage. This is a standard 555 monostable circuit based on IC1, and it is triggered when the voltage



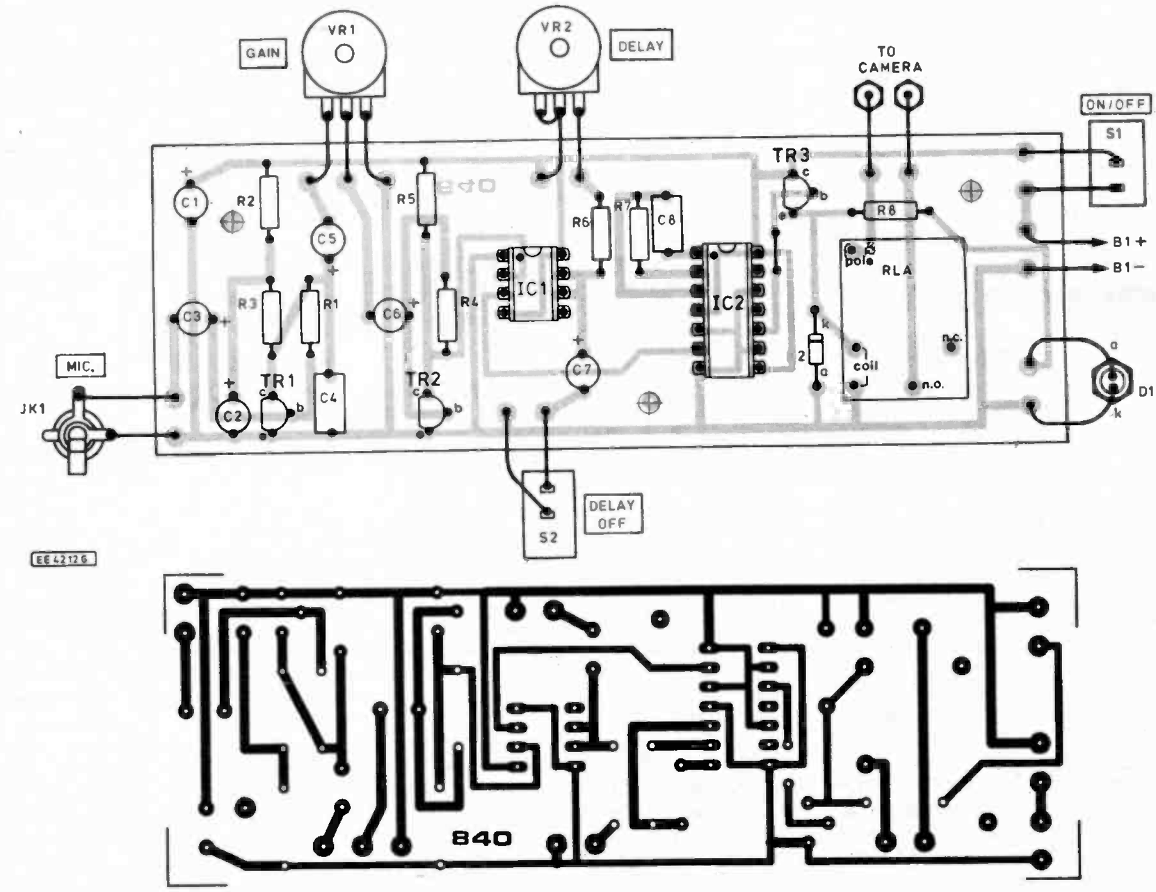


Fig. 3. Printed circuit board component layout and full size copper foil master pattern for the Sound Activated Camera Trigger unit.

tery supply, which is comprised of eight HP7 size cells in a plastic holder. A 12V supply is needed in order to guarantee that the relay will operate properly once the battery voltage has fallen slightly due to ageing.

In practice, the unit will almost certainly operate properly from a 9V battery even when the battery voltage has fallen somewhat below 9V. It is worth trying a 9V battery (e.g. six HP7 size cells in a plastic holder) as this significantly reduces the running costs.

The current consumption from a 12V supply is about 10 milliamps under standby conditions, but is three to four times this figure while the relay is activated.

CONSTRUCTION

Details of the printed circuit board topside component layout and underside copper foil master pattern are provided in Fig. 3. This board is available from the *EPE PCB Service*, code 840.

The first point to note is that the 4047BE used in the IC2 position is a CMOS device, and that it is not fully static-protected. It is therefore important to observe the normal anti-static handling precautions when dealing with this component.

It should be fitted in a holder, and it should not be plugged into place until construction is complete in all other respects. It should be left in its anti-static packaging until then, and handled no more than is really necessary while it is being fitted into its holder.

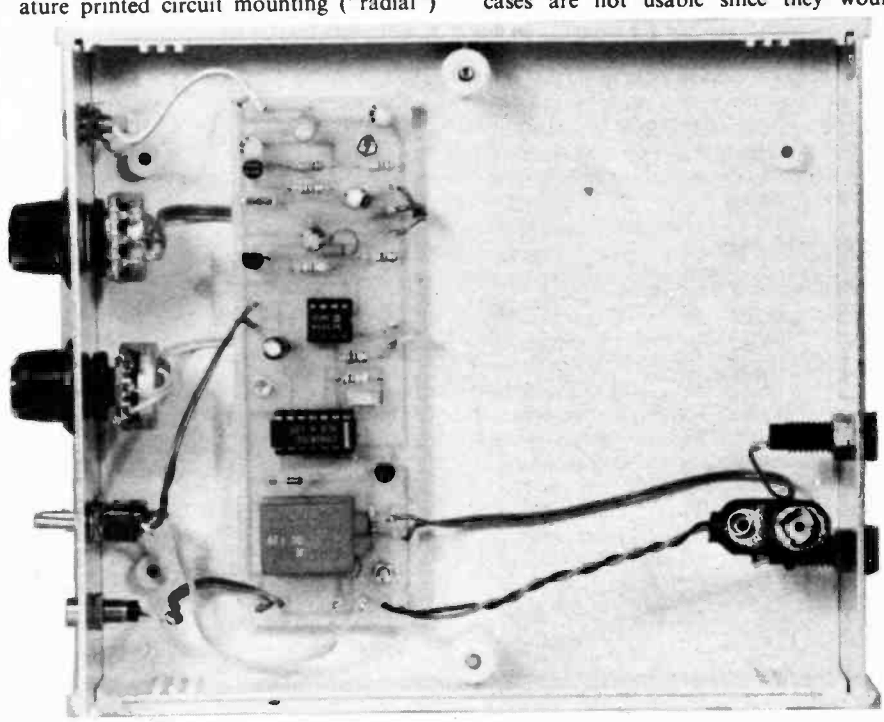
The printed circuit board has been designed to accept the specified relay, it is unlikely that any other type will fit into this layout properly. It is strongly recommended that the specified relay should be used unless there is a very good reason for using an alternative type. If an alternative relay is used, it will probably have to be mounted off-board and hard wired to the printed circuit board.

The specified relay has contact ratings of 30V d.c. and 10A for resistive loads (3A for inductive loads). This should be substantially more than adequate for the current application.

In other respects construction of the board is quite straightforward. However, the electrolytic capacitors must be miniature printed circuit mounting ("radial") types if they are to fit easily into the available space. For the same reason the polyester capacitors should be miniature printed circuit mounting types having a lead spacing of 7·5mm (0·3 inches).

Single-sided pins are fitted to the board at the points where connections to the off-board components will eventually be made. The tops of these pins should be generously tinned with solder.

The unit should fit into practically any medium size plastic or metal case. Small cases are not usable since they would



not accommodate the battery pack. The fairly high current consumption of the unit renders small batteries unsuitable.

The controls, l.e.d. D1, and socket JK1 are mounted on the front panel. As with any sensitive audio circuit, it is advisable to choose a front panel layout that will avoid a lot of long and crossed-over wires when the hard wiring is installed. A 3·5 millimetre jack socket is specified for JK1, but this can obviously be changed to a different type to match the plug fitted to the microphone you will be using.

PLUGGED-IN

The method used to connect the unit to the camera must be varied to suit the particular camera that the unit will control. On the prototype the relay contacts are wired to a pair of four millimetre sockets mounted on the rear panel of the case. These sockets match the plugs fitted on the Nikon remote control lead for the F4 series of cameras. A few other cameras have remote leads fitted with these "banana" plugs, as they are sometimes called.

A number of cameras have a remote control lead which is terminated in a 2·5mm jack plug. This is the nearest thing to a standard remote lead connector, but it seems to have fallen from favour in recent years. Of course, for use with such a lead the unit must be fitted with a 2·5mm jack socket.

If the remote control lead has some form of non-standard or unusual connector at the controller end, it is probably best to cut the connector off and then solder the lead directly to the printed circuit board. An entrance hole for the lead will then be needed in the rear panel of the case, and this hole should be fitted with a grommet to protect the cable.

INTERWIRING

Details of the point-to-point wiring of the front and back panel mounted components are also shown in Fig. 3. It is not essential to use a screened lead to connect JK1 to the circuit board provided this lead is kept very short (no more than about 20mm to 30mm long). The cathode ("k") terminal of the l.e.d. D1 will probably be indicated by a "flat" on that side of its body, and by the cathode lead being shorter than the anode lead. However, if necessary the correct method of connection can be found by trial and error, since connecting D1 the wrong way round will not result in it sustaining any damage.

The rest of the wiring is very simple and should not give any problems. Connection to the battery pack is via an ordinary PP3 type battery connector.

IN USE

The unit is designed for operation with a low impedance (200 ohm to 600 ohm) dynamic microphone, but will actually work with practically any type of microphone (high impedance dynamic, electret, crystal, etc.). Audio quality is obviously of no importance in this case, and a cheap "cassette" type dynamic microphone is probably the most practical choice if you do not already have a suitable microphone of some kind.

Initial testing should be carried out with the unit not connected to the camera. Instead, the l.e.d. D1 is used to determine whether or not the unit is triggering properly.

With the sensitivity control (VR1) well advanced, even fairly quiet sounds should get D1 to flash for about half a second. However, the sensitivity is largely dependent on the characteristics of the microphone used, and will vary considerably from one microphone to another.

Remember that many microphones (particularly "stick" types) are directional, and that for maximum sensitivity they must be aimed at the sound source. Even using a relatively low output microphone, with the sensitivity control well advanced it should be possible to obtain a maximum operating range of several metres using a shout or hand-clap to activate the unit.

Check that the Delay control VR2 enables the delay time to be varied, and that switch S2 enables the delay to be removed completely. If everything seems to be functioning properly, connect the camera to the unit and check that it will trigger the camera properly.

When using the unit in earnest it is a good idea to always do a trial run before switching on the camera and taking the shot. Things may not always go according to plan, and with this type of thing you have to accept that the odd frame or two of film will be wasted from time to time. Having the sensitivity advanced no further than is really necessary helps to keep down the amount of unwanted triggering due to unexpected background sounds.

SPECIAL EFFECTS

If the unit is used to take shots of water splashes, breaking glass, etc., suitable precautions to protect both the equipment and anyone in the vicinity must be taken where appropriate. The unit can be used to trigger an electronic flashgun rather than the camera, should you wish to use that method of working.

Bear in mind that instant triggering will never be achieved. The trigger unit will probably take a millisecond or two to respond to sounds, and the sound will take about three milliseconds per metre to reach the microphone.

These delays are quite small, but they can sometimes be significant. For rapid triggering it is clearly best to have the microphone as close as possible to the sound source.

If the unit is used to trigger an SLR camera it is likely that the camera itself will introduce a significant delay. Apart from a few specialist cameras such as the Canon EOS RT, there is usually a delay of about 40 to 80 milliseconds between triggering and the shutter responding. Where fast triggering is needed, the sound triggered flash method is likely to give much better results. □

Innovations

A roundup of the latest Everyday News from the world of electronics

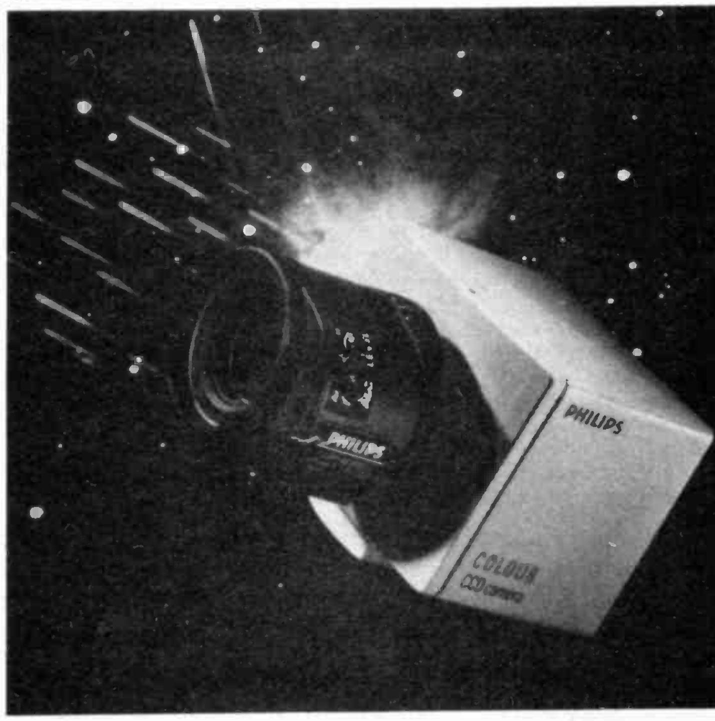
ON CAMERA

Fuzzy Logic joins forces with the microprocessor to spotlight the problems in security surveillance and public crowd control.

Two new colour CCTV cameras from Philips, models LDH803 and 805, feature built-in intelligence and automatic image enhancement. One model, the 805 provides a unique colour/infra-red switching capability for day and night surveillance.

The new cameras feature fully automatic image processing, which, it is claimed, provides clearer, sharper images with more detail and improved colour rendition in virtually any situation including difficult or changing light conditions right down to 0·6 lux. The operator can also override automatic operation just by selecting any of three pre-set modes for different light conditions or viewing requirements during the day. Other useful features include a 24 character alphanumeric text-in-picture display to keep operators fully informed of camera location, status, mode and messages.

The new cameras have been designed for the widest possible range of applications covering urban and city centre surveillance, shopping centres, traffic, public safety surveillance in railway stations and airports, museums and perimeter surveillance. The 805 has been successfully installed at Wembley Stadium, which receives eight million visitors each year.



Picture Enhancement

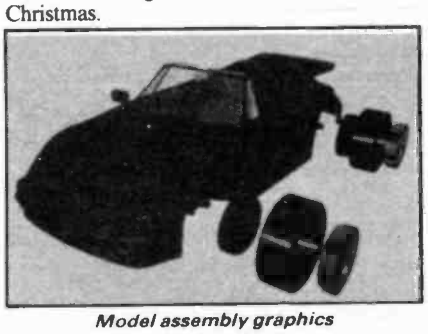
Both cameras use a built in microcomputer and unique fuzzy logic to provide a full range of automatic image enhancement and control functions. The microcomputer continually analyses the video signal and automatically enhances the picture to provide improved images.

Advanced image enhacement features fully Automatic Histogram Equalisation to improve light level and colour balance and provide more in highlights and dark areas, Contour Enhancement for clearer images and auto-white control for more accurate colour balance. Other major features include selectable weighted backlight compensation to improve detail in areas with strong backlighting from windows or lamps, and exposure time control to reduce movement blur. In addition, a 24 character text-in-screen facility gives the operator an instant display of camera location and mode.

CD ROM KIT/GAMES

A NEW range of kit/games is being launched by Revell the model kit suppliers. Revell have combined an interactive CD ROM game with a range of kits for cars, planes, dinosaurs and spaceships so that you can build the car of your dreams, drive it to the racetrack, tune it for racing and then compete in a full race with pit-stops, randomly changing weather conditions etc. If you win there is even a "bodacious babe" to congratulate you.

The whole idea looks like a winner and the computer games seem to be very well thought out and executed. There are four different cars available in the Motor Stars range, of the Porsche 911 slant nose sports racer variety. The other ranges will be launched before Christmas.



Model assembly graphics

View from the drivers seat of the 911

In addition to a Road Race and Track Race (with four road and track circuits to choose from), the CD ROM also includes instruction and tips on building and painting the plastic model. Animated three dimensional graphics of each model part float together on screen to make it easy to see how to assemble the kit. Various facts and performance figures for each car are also included. You can even view the finished kit in various colours before you decide which colour to paint it.

Revell have also included pictures of 50 of their lastest models in a "graphic catalogue". The price of all this is £59.95 but you will need a 386 or better PC running DOS 5.0 or higher and having 4MB RAM, SVGA graphics (VESA compatible), CD ROM drive, Soundblaster or Adlib with speakers or headphones, mouse or joystic and 13MB hard drive. We guess you will also need plenty of spare time, it looks very addictive. The first Motor Stars releases are in the shops now.

APPLIANCE TESTER

AN Information Technology (IT) Portable Appliance Tester, the MEGGER® PAT32, available with a combined analogue/digital display, has been announced by AVO International.

The introduction of the 100mA continuity test specifically required by the Electrical Electronic Association (EEA), makes it an ideal instrument for testing computer installations, office and other electronic equipment. The calibrated analogue/digital display offers the twin benefit of being able to quickly assess the test result from the calibrated scale and then to have a digital reading to record results.

Another feature of the analouge scale is the easy identification of faulty earth connections; rapidly changing values are not visible on digital only instruments. The PAT32 is a dual voltage instrument powered from 240 volts, with the standard 240V and 110V sockets situated conveniently on the front panel. With the aid of the optional Extension Lead Tester, ELT1, all extension leads, both 110V and 240V, as well as IEC mains leads, can be checked for polatiry, continuity, and an insulation test can be perofmred.

The PAT32 is not only suited to site applications but to the commercial, educational or medical establishments where a qulity, simple to use appliance tester can help meet the requirements of preventing danger.

Test results obtained from the combined analogue/digital display should be stored on either a laptop computer or sheet of paper in a log book to be compared so any degradation in the recorded values can be spotted. The MEGGER® Test manager II software (also from AVO) allows exactly this facility and offers the company user or the contractor complete traceability in the event of a failure of a tested appliance.

For more information contact AVO International, Dept EPE, Archcliffe Rd., Dover, Kent CT17 9EN. Tel. 0304 202620. Fax. 0304 207342.

EUREKA!

Last year's record number of new advanced technology projects under the EUREKA initiative has been exceeded this year, Technology Minister Patrick McLoughin has just revealed.

EUREKA is a pan-European framework for promoting collaborative R&D in fields of civil advanced technology with the aim of improving Europe's competitiveness in world markets. A total of 193 projects were announced by the 21 EUREKA members covering a wide range of technological areas.

The 49 UK projects announced at the eleventh EUREKA Ministerial Conference in Paris, France, involve a total of 76 UK Organisations including 28 small to medium-sized enterprises and 17 Universities or research establishments. UK organisations are in the lead in 15 of these projects.

Just the TickIT

The three-hundredth TickIT award – the quality certification for software – was made to BT recently.

The cost of poor quality software was estimated, in 1988, to cost the UK £500M per annum, in the traded sector alone and some £2 billion when scaled up to include software developed in-house.

THE THINGS PEOPLE PATENT!

The following abstracts are taken from recent UK patent applications in the general electrical/electronics area. British Patent Specifications can be ordered from The Patent Office, Sales Branch, Unit 6, Nine Mile Point, Cwmfelinfach, Cross Keys, Newport, Gwent, NP1 7HZ.

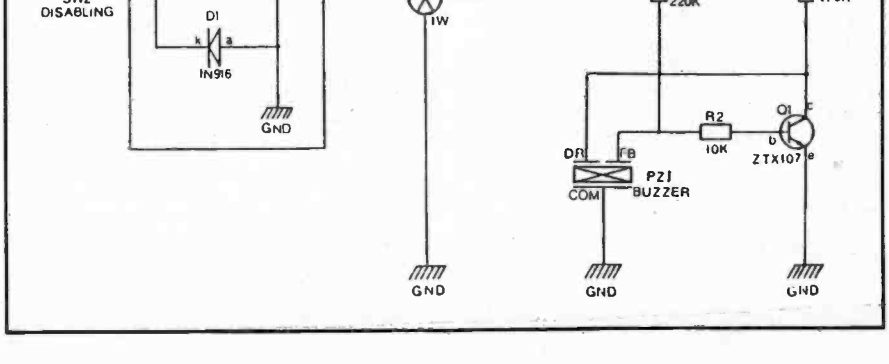
Identifying faults in electric circuits

In UK patent 2249398 Genrad Ltd. describe a system for identifying faults in electric circuits such as in vehicles. Data describing the circuit is stored and data indentifying a fault symptom is fed into the system to indicate that for one set of circuit conditions an intended output is not provided by the circuit. Stored data is examined and then describes selected components which, if faulty, could cause the symptom.

Values of electrical variables to be expected at certain points in the circuit are calculated. Electrical variables are measured and data fed into the system. The input measurement data is compared with the calculated electrical variables and faulty components are indentified from the comparison.

Universal digital input channel

In UK patent 2249840 Alireza Ghazi Hessami describe a universal digital input channel. To detect the on/off state of a switch in a circuit, including a source and a varistor, a bridge rectifies the voltage existing across the varistor and energies a circuit including two transistors and two l.e.d.'s. One of the l.e.d.'s is an opto-isolator device in an output circuit including an amplifier. With the switch on, both l.e.d.'s emit light and an electrical output is produced by the amplifier.



Testing emergency lighting systems

In UK patent 2258571 Protec Fire Detection plc describe a system for testing emergency lighting systems. The system has a number of emergency lighting units, each having a lamp which is connected to a battery on a mains failure. A detector senses light from the lamp and a central control unit sequentially senses the outputs from the detector.

Each lighting unit has a unit for counting timing pulses on a data ring. When the counter reaches a programmed count identifying that unit, a switch is closed so that signals are passed to the ring from a logic circuit having inputs connected to detector and a battery charging current sensor. A particular control signal applied to a ring by the central unit causes a test latch to open a mains switch to simulate mains failure. The lighting units may be divided into groups, a different group being tested on each of the first 28 days in each month.

A device for giving a signal or message in a vehicle

In UK patent 2258436 John Rhys Condon describe a retrofitted or dashboard-incorporated signalling unit in a land, sea or air vehicle. It can give a reminder such as "Keep Left"; convey an advertisement; give a message e.g. "Starting" or switch on a pre-recorded message. It consists of an electrical circuit. The circuit comprises a self latching device disabling a switch SW2, sound and light indicators and on/off indicator switches.

The circuit is enabled by the ignition switch and disabled by the disabling switch. On enabling indicators are activated; deactivation occurs on operating the disabling switch SW2 or deactivating the ignition switch SW1. The self latching circuit can be either solid state or relay based and actively latched or latched during disable. The indicators can be simple state, oscillating or vibrating devices or mixtures of both.

New Technology Update

Ian Poole reports on single electron memories and new transistors for power i.c.s.

ONE of the main areas of development in the electronics industry is focused upon computer memories. In the past months in this column we have reviewed various new ideas for semiconductor memories as well as disc based ones.

As the thirst for all forms of storage seems to be growing as fast as the technology expands this emphasis is unlikely to change. As a result, new and revolutionary ideas are surfacing all the time. One which has just recently hit the headlines is an idea for memories which use a single electron to store each bit of data.

This idea could have a vast impact on computer technology because terabit (i.e. 1,000 gigabit or 1,000,000 megabit) memories now become a possibility. The development is also very important because current semiconductor technology has limitations beyond which further improvements will not be possible.

It is estimated that today's technology will be able to be improved to give memories with a maximum size of 50 Gbits. Any improvements beyond this will need a new form of technology.

Terabit Memory

To illustrate this point, if a Terabit memory could be made using existing technology it would occupy many square metres. In addition to this it would consume an estimated ten kilowatts of power.

Clearly this would not be feasible. However the new electron memories should be capable of producing storage of this size in a space just over a square centimetre. The power would also be drastically reduced. The memory would consume about a tenth of a watt. On both counts the new electron memories give improvements of many orders of magnitude. It is because of these improvements that there was a tremendous amount of excitement in the electronics world when the idea was announced.

This new memory is the result of work performed by the Hitachi Cambridge Laboratory and the Cavendish Microelectronics Research Centre, Cambridge University. It is described in a paper entitled *Single Electron Memories* which appeared in the IEE publication *Electronics Letters*.

A conventional memory requires about half a million electrons to be controlled for each bit. Reducing the number of electrons which have to be manipulated obviously reduces the size, current consumption and heat dissipation of the device.

Blockade Effect

In the new memory development it is possible to control just a handful of electrons. This is accomplished with a technique called the "coulomb blockade effect". Using this it is possible to control a current flow by blocking or allowing current to flow depending upon whether a capacitor is charged or not. Detecting whether current is flowing indicates the state of the capacitor and hence the data stored in it.

The circuit is built on a layer of Gallium Arsenide about 20nm thick and doped with silicon. This creates a two dimensional plane in which the electons can move. The actual circuit of the single cell is about 0·03mm across with element dimensions of about a micron.

Currently the system only works at temperatures within a degree of absolute zero, and between ten and a hundred electrons are needed. However theory predicts that it will be possible to use the system at room temperature using a single electron.

The Future

This new memory is still in its very early stages of development. The basic idea has been proved, but a vast amount of work is still needed before it will be possible to utilise it for commercial products. This means that devices will not be available for at least 20 years. One of the major reasons for this is that nano-metre dimensions are needed to realise the memory.

Such dimensions are well below anything that can be achieved today. However to assist in the development Hitachi themselves have started work at their central laboratories in Japan. Here they are using a scanning tunnelling microscope. This machine was developed by IBM for use with their atomic level switch which was reported in the *New Technology Update* in the November 1992 issue.

It is expected that the next devices to be assembled will be single elements to develop the basic technology. To produce more complex devices including a complete cell will take several more years of development. Only then can work on a large memory device begin.

When complete memories are finally available they should revolutionise the computer industry. They will enable vast memories to be included in desktop computers, giving them memories currently available in only the largest mainframe computers. This should prove to be an important stepping stone for other revolutionary developments which are currently beyond the horizon.

New Transistors For Power I.C.s

There are many other areas where i.c. developments are taking place. One has arisen because there is a growing need to include power transistors into i.c.s. A new development in this area has enabled greater efficiency to be achieved whilst reducing the size and using less complex processes.

These new transistors have been made possible because of the introduction of lateral transistors into a DMOS (Double diffused Metal Oxide Semiconductor) process. Transistors are formed laterally or along the surface of the semiconductor. Previously vertical structures had been used to save space. Now the smaller geometries which can be used have allowed the use of lateral transistors.

Advantages

The new transistors have several advantages over their predecessors. In the first instance they are far more efficient and have a much lower "on" resistance. For a given area the resistance can fall by a factor between two and five when compared with vertical transistors.

As a result of this increased efficiency the transistors can be made smaller. In turn this means that more space is made available on the i.c. for other circuitry. This can be used for more circuitry and the i.c. can have more functionality.

A further advantage of the new transistors is that they are self-isolating. As a result they do not need any additional stages in the manufacturing process to add isolation zones. This means that the new i.c.s only need eight masking processes; a particularly attractive feature because it enables processing costs to be reduced.

Finally the new process simplifies on-chip noise problems. When switching significant amounts of current other circuits on an i.c. can be affected. To overcome this problem guard rings are placed around the switching circuits. This cure has been so effective that switching noise from circuits off the chips cause more problems. However standard filtering techniques can be used to reduce this.

The new technology has many benefits. In the first instance the transistor efficiency improvements have enabled power i.c.s to be manufactured that dissipate just half the power of previous generations.

The process can also be used with VLSI or analogue chips. This means that in the future far more flexibility can be offered within high power chips. For example it will be possible to have a micro-controller and its power switching devices on the same chip. In fact this development will allow power switching in d.i.l. packaged i.c.s. This is particularly importance for equipment manufacturers because it allows for simpler board assembly and reduced costs.

CONSUMER ELECTRONICS SHOW - CHICAGO

Barry Fox reports on developments from the annual Chicago Exhibition.

THE annual summer Consumer Electronics Show in Chicago is accurately reflecting changes in the industry and marketplace. As homes saturate with audio, video and TV hardware, the manufacturers are feeling the pinch. To survive they must either branch out into software, develop completely new ideas for home entertainment or persuade people to buy business equipment and turn their homes into offices.

At this year's CES we saw a significant reduction in the number of big name manufacturers of conventional audio, video and TV equipment. Their places on the exhibition floor were taken by firms selling video games, hand held computers, fax machines and telephones. The big issue was the battle between Philips and newcomer 3DO, to create a new standard for multimedia home entertainment.

US trade magazine *TWICE* (This Week in Consumer Electronics) proved with a survey what trade and press visitors had been telling each other. So many major manafacturers were missing this year that less than half the trade visitors were satisfied. Exhibitors e.g. Sony and Pioneer, were booking hotel suites around town instead of booking space in the McCormick Exhibition Centre. This is making the Chicago CES more and more like the awful Spring Brown Goods Show in London, where there is no cental exhibition site, just dozens of hotels straggled over London.

"Too many companies are taking advantage of the show without paying for it" said *TWICE*. This is what helped kill the UK's Harrogate Hi-Fi Show. In what turned out to be that show's final year, Pioneer ducked out of the official show and took over part of a local department store.

Small wonder that the groundswell of opinion at this year's CES was that next summer's Show could well be the last.

Kodak showed a portable Photo CD player which plugs into a TV. This should be a winner for business, and will make it easier to show Granny electronic images of the kids.

CD-ROM GAMES

A side hall of games exhibits, centering on Sega and Nintendo, buzzed with excitement even on trade-only days. The PC companies were pushing CD-ROM games and education titles for use on PCs equipped with add-on CD-ROM drives, sound cards and active speakers. But this push glosses over the practical problems created by inherent deficiencies of the IBM PC which make it difficult to add more than one peripheral without their control signals and system settings (e.g. IRQ, DMA, I/O address) clashing to stop the system working.

It is a brave, or foolish, dealer who sells CD-ROM equipment without a good understanding of the technical problems customers are sure to hit.

Big names missing from the main hall included Sony, Pioneer, Canon, Casio, Fuji, Sharp, Hitachi, JVC, Toshiba and Mitsubishi. Their floor space was taken over mainly by telephone companies and vendors. The lower hall resembled a bazaar, with much cheap tat from many "no-name" companies in the Far East.

The public, who can get in over the last weekend, doubtless jumped at the chance to play the latest video games, like Sega's Jurassic Park. This features dinasours who spit at explorers magically blessed with the ability to jump vertically like fleas.

DIGITAL COMPACT CASSETTE

Philips was showing DCC audio but the absence of Sony and Sharp left Mini Disc virtually forgotten, with rumours circulating that Sony may even be considering a relaunch of MD, with improved sound quality.

Philips joined with Panasonic for a breakfast press meeting at which Ted Abe of Technics re-ran a watered-down version of the demonstrations he gave the European technical press at the recent seminar in Wiesbaden. These involve copying music from CD to DCC and MD, many times over.

While DCC sound suffer little from multi-generation copying, MD dubs soon sound very rough. Philips makes the valid point that accentuating system errors by multiple copying, teaches audio engineers how to home in more quickly on more subtle faults.

But behind the scenes politicking (with Philips's US subsidiary not keen to join with rival Panasonic) made the event half-hearted, overlong and dampened by a rambling introduction by Gerry Wirtz of Philips. Technics did it far better in Wiesbaden.

WRISTWATCH PHONE

Panasonic launched the KX-T9900, a wristwatch-sized cordless telephone that operates in the 900MHz band, instead of the 46/49MHz band used by existing cordless telephones in the USA. The higher frequency, close to cellular phone bands, reduces the size of aerial needed. The cost, though, is $1000.

Panasonic also launched an all digital, 900MHz, cordless phone of size similar to a cell phone. The selling point is that, like CT2 phones in the UK, there is no risk of interference or crossed line eavesdropping. But Panasonic is likely to find what purveyors of CT2 have found in the UK, that the price ($400) is so much higher than for conventional analogue cordless phones, that most people stay with analogue technology.

PLAIN TREND

The clearest new trend was towards plain paper fax machines. These use either a Xerographic printer drum, like a plain paper copier or laser printer, or a bubble jet, as also used in computer printers. Clearly the days of curly fax paper that fades after a few months are numbered. No-one, except the fax paper

Panasonic's wristwatch-sized cordless phone in use and (right) its base station.

suppliers, will shed a tear on this. But there is still no sign of the obvious winner product, a single unit that trebles as computer printer, copier and plain paper fax machine.

RE-CHARGE ALL

It is now at least ten years since Fidelity in the UK unveiled a portable radio that ran on conventional, expendable batteries, but re-charged them with a clever combination of d.c. and a.c. voltages. The radio was forgotten even before Fidelity.

Since then there have been several articles in specialist electronics magazines telling how to make a charger for supposedly non re-chargeable batteries. Innovations International, of Richmond, Surrey and Northbrook, Illinois now promises the "Battery Manager", which for $40 and upwards claims to re-charge all types of batteries, automatically controlling the type of charge needed.

US RDS

The Radio Data System, RDS, is now reaching into America. The National Radio Systems Committee, NRSC, has finalised what it calls the American Radio Broadcast Data System. RBDS is virtually the same as European RDS, but without the EON (Extended Other Networks). EON is not necessary in the USA, because there is no national network comparable to the BBC. For a station to provide EON would simply switch its listeners to another rival channel.

RBDS does, however, have TA, the traffic announcement system which automatically switches the receiver from CD or cassette playback when a local radio station is transmitting a traffic announcement. The AF, alternate frequencies, function is also used to seek out the strongest signal for a name station.

A modification of RBDS, called Coupon Radio, adds a decoder which can store any text information, for instance music title, phone number or restaurant address, into a smart card. The stored text can either be displayed on an LCD screen at the end of the journey or printed out onto a coupon, which the driver uses as a calling card or credit voucher for a special offer.

DISGUISE

Questech International offers the Transition, which for $100 upwards, uses digital circuitry to disguise the voice of someone making a telephone call. The circuit can be switched to increase the pitch, lower the pitch or make the caller sound like Mickey Mouse. "Your own mother won't even recognise you", boasts Questech, and it is probably true.

Quality is quite poor, but disguise is effective. Although Questech says its gadget "discourages annoying or obscene telephone calls" it could, of course, equally well be argued that the same system can be used to disguise the voice of an unwelcome caller.

The Magnavox DCC player.

CD-I DESIGN CHANGE

Philips' demonstrations at Chicago highlighted a design omission or error in the original CD-I specification. The player front panel connection only enables one games controller at a time. This crippling restriction was born out of Philips original rather grand notion that CD-I would be an educational tool, not a games machine.

But now Philips has changed tack, and claims that fun is the name of the CD-I game (see heading photo). So demonstrators at Chicago were using two controllers, one plugged into the rear and one the front of the CD-I player.

But this falls outside the "Green Book" standard, because the system is designed to disable one controller when the other is connected. It is easy to write CD-I software which allows both the front and rear ports to work at the same time, and provide support for two players, but the Green Book standard must be re-written. Pressure is mounting on Philips to make this change as soon as possible.

ZOOMER

A small side exhibit of computer equipment showed the trend towards personal digital assistants or personal communicators, typified by the Zoomer from Tandy and Casio. PDA/PPCs allow the user to write on a pressure sensitive LCD screen, which registers script, converts it into computer text and stores it. But until conversion is faster and more accurate, many people may prefer to use a keyboard or notebook and pencil.

CAR-JACKING

In the USA car highjacking has taken over from car theft. When a car stops at traffic lights, a criminal opens the door, jumps in and throws out the driver. The Lasso, from Protect and Defend Inc. of Merrifield, VA, is hailed as the answer. It cost from $200, and drivers get $2000 in cash if it lets them down.

If the car is stolen or the door is opened while the engine is running, a sensor trips to start a clock. After about 75 seconds, warning lights flash and a synthesized voice says in two languages "Pull over now. The engine is about to stop and loud sirens will sound. Get out of my vehicle".

The FZ-1 REAL 3DO multi-media player, perhaps not quite as real as it looks.

After 100 seconds, deafening sirens blast both inside and outside the car. After 120 seconds, the engine switches off and the sirens sound again.

The legitimate owner of the car can disable the Lasso by pressing two flush mount switches which can thus be hidden behind leather or upholstery trim.

3DO MULTIMEDIA

"Panasonic unveils first 3DO multi-media player – breakthrough technology set for September delivery . . . multimedia becomes REAL", read the publicity material for Panasonic's 3DO player, called the FZ-1 REAL. "Show goers were amazed by the powerful graphics that are fifty times better than the current 16-bit video systems . . . the REAL uses software based on a revolutionary new architecture that will enable consumers to enjoy entertainment, educational and informational programmes with performance levels fifty times greater than existing personal computer or 16-bit video game systems".

The REAL, says Panasonic, is "officially scheduled to be shipped to dealers in September with a suggested retail price of $700...the REAL will be available in September 1993".

"The crowd around our booths seem to be enjoying the great 3DO titles on display... We feel the 3DO system will become the standard in interactive media, just as VHS has become the worldwide standard in home video", says Richard Lovisolo, Panasonic's Vice-President.

"At the same time the hardware reaches store shelves exciting software will be introduced as well . . . once (people) see the graphics, hear the sound and recognise the potential, the FZ-1 will sell itself".

"Imagine an interactive CD system that gives you real-time interactivity and living images of laser disc quality", says Lovisolo. "This is what the Panasonic FZ-1 REAL 3DO Interactive Multiplayer and 3DO are all about".

"We're on track for the Fall hardware launch and a wide variety of software will be available for Christmas", 3DO's President and Chief Executive Officer Trip Hawkins promised.

"Seventeen software companies showed 35 titles at the CES" says 3DO. "The 3DO company unveiled its breakthrough technology at the CES show last January (1993). Since then the company has concluded a successful initial public offering, raising more than $48 million"

REAL SMOOTH

3DO's press conference was by far the biggest event of the whole show, quite literally standing room only in a large hall, with fire officers worried about over-crowding. It took only a few moments of the solo performance by 3DO President and Chief Executive Officer Trip Hawkins to see how Panasonic came to back the system, and how shareholders came to put up $48.5 million when the company made its first public offer of shares.

Smooth, dynamic and charismatic, Hawkins is the consummate salesman. He pours forth a warm and seamless stream of claims, promises and predictions that sound immensely convincing. Doubts wash away before they have time to form.

Most signficant, Hawkins closed the press conference without a question and answer session. Panasonic did not even hold a press conference. So no-one got the chance publicly to challenge any of the claims made by 3DO or Panasonic in their literature, or by Trip Hawkins in his appearance.

This always makes me suspicious. So I looked a little closer at the ostensibly impressive demonstations being given in the exhibtioin hall by both companies.

REAL – PERHAPS NOT?

The heart of the 3DO system is a computer chip, using RISC (Reduced Instruction Set Computing), which lets the system works faster. The operating system is new, and proprietory to 3DO. AT and T is making the chips. Speed is increased by using dedicated graphics processors.

The program software all comes from a CD-ROM, but, as happens in modern CD-ROM drives for personal computers, the disc is run at twice normal speed to double the data transfer speed from 150 kilobytes/second to 300 kilobytes/second.

All this makes it easier for the 3DO player to generate fast moving images, of arcade quality, without "fade outs" while the player searches for the next chunk of data from the disc. But it also halves disc capacity, which is of special relevance for full motion video (FMV).

Despite double speed running, Panasonic players were delivering very poor quality FMV pictures, both on the 3DO stand and Panasonic stand. The Panasonic player had a cartridge, labelled FMV, clipped to the side, and the demonstrator was telling visitors to the stand that it was a "working player". But he later admitted when pushed hard, that the FMV cartridge was a "mock-up" and that the system was running from a "development station" hidden behind the booth walls.

On the 3DO stand a REAL player was running the FMV game Twisted. This player, too, had no disc in it. Only when pushed hard would the demonstrator admit that it was "running off a development system" hidden behind the stand.

Another REAL player on the Panasonic stand was running a car race game. The demonstrator told me it was a "working player". "I don't believe you", I said, and pressed the Disc Eject button. There was not even a disc in the player tray.

"I was told it was a working model", the demonstrator explained, adding with obvious sarcasm, "Isn't that awful".

Later I followed the wires from the REAL's remote controls back through a hole in a partition behind the player, to a hidden bank of Apple Quadras. The Quadra is Apple's top of the range Macintosh computer, used for its speed and graphics capability. The demonstrator then admitted that the Quadras were being used to "boot" up 3DO circuitry also hidden behind the stand.

BELIEVED WORKING!

At a meeting with Panasonic PR men, they claimed to believe that all the players were "working models", but admitted that the large projection screen display over the Panasonic booth was sourced from three-quarter inch tape.

On the 3DO stand another Panasonic player was running FMV clips, apparently without any hidden workstation to drive it. But when we asked whether the player would do anything other than run FMV clips the demonstrator had to admit that it would not. After we opened the tray to satisfy ourselves that there was a disc there, the demonstrator could not get the player working again.

One REAL player on the 3DO stand was demonstrating FMV, supposedly with the C-cube MPEG-1 chip built in, and data running at between 1·5 and twice normal speed. Quality was nowhere near as good as that which the Philips CD-I player was delivering at single speed elsewhere in the hall.

Yet another REAL player on the 3DO stand was demonstrating Photo CD, apparently from its own electronics. Again we asked if the player would run any other disc. The demonstrator said it would and we asked for a demonstration. "All right, I'll call your bluff", he said, and went away to get another type of programme disc. Sheepishly he returned admitting that his player would only work with Photo CD or audio discs.

"The product isn't on the market yet", he explained. "Come back in January", said 3DO's increasingly vexed PR lady, Sue Bohle.

There is no shame in simulating chip performance from workstations. But it is surely dangerous to try and disguise the fact, because it casts doubt on other claims. When Hawkins held up a player circuit board at the press conference, (later shown nationwide on television) and claimed that it was real and ready, how real was it?

Back in the UK I faxed both Panasonic and 3DO in the US and asked whether they stood by their pledge to ship players in September. Both said "Yes".

Trip Hawkins says it it is misleading to describe the players as dummies or single task players. But he goes on now to admit that "things are unfinished" and that demonstrations at Chicago relied on Quadra development systems, and on players capable of performing only single tasks.

FINAL – PERHAPS!

Panasonic also now admits that some electronics was hidden from view. But whereas Trip Hawkins explains that the players shown did not contain the "final chipset" Panasonic's spokesman Bill Pritchard says "the players were final prototypes" and "complete", with only the program software coming from the hidden Quadra.

Pritchard seemed unaware that demonstrators on his own company's stand had described the Quadras as "booting" the players and that a demonstrator on his stand was showing a player with FMV adaptor on the side which he later admitted was a mock up.

Why hide the extra electronics needed to make the system work? "I don't know" says Pritchard "is it necessary to show the man behind the curtain as in the Wizard of Oz?".

Will 3DO and Panasonic really be able to launch REAL in September/October as so clearly promised? Will the launch hardware and software live up to the companies' grand promises? 3DO's shareholders only have to wait until October to find out.

DOWN TO EARTH

George Hylton

IMPEDANCE

Impedance is anything measurable in ohms. In addition to resistance itself impedance includes the current-resisting effects of inductance and capacitance. These effects are called *reactances* rather than resistances.

Why make the distinction? Well, resistances in series just add together: 200 ohms +100 ohms =300 ohms (Fig. 1a). Reactances don't always behave so simply.

An inductive reactance (i.e. the impedance of an inductance) tends to cancel the reactance of a capacitance when the two are in series. If we say inductive reactance is positive and capacitive negative

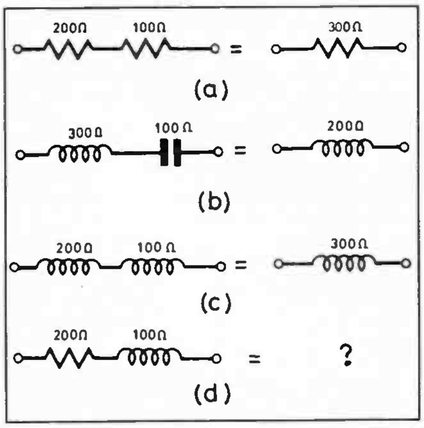


Fig. 1. Impedances in series and their simplified equivalents.

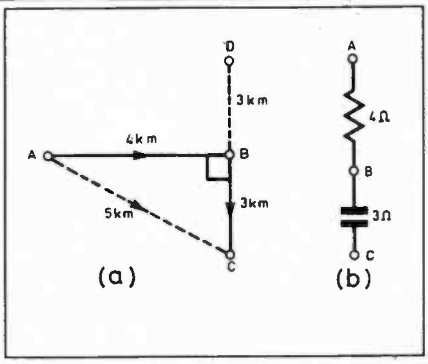


Fig. 2. A traveller's journey from A to C via B provides a good analogy for mixed impedances like Fig. 1d.

then 300 ohms (inductive)+100 ohms (capacitive) = 200 ohms (b). Connecting the two in series has *reduced* the overall impedance.

Reactances add like resistances only if they are of the same kind (c). If three *identical* coils are in series then the total reactance is three times the reactance of one single coil. Similarly with capacitors. Put three identical capacitors in series and you get three times the reactance of any one of them. But once inductances and capacitances are mixed the "cancellation" effects occur, sometimes with surprising results.

FORBIDDEN SUMS

What happens (d) to the impedance when a resistance is put in series with an inductance? Something complicated! They don't just add. In fact you end up with an impedance which is *less* than the *sum* of the two reactances, but greater than any one of them.

When I said earlier "If we say inductive reactance is positive . ." the important word was "If". It's certainly positive compared with capacitive reactance. But compared with resistance it's neither positive nor negative but somewhere in between.

ROAD ROUTES

This awkward situation can be made a bit easier to understand by an everyday analogue (Fig. 2). A traveller wants to drive from A to C but there is no direct route. He is forced to go from A to B then make a right-angled turn. In reaching C he has gone 4+3=7km, yet as the crow flies he's only gone 5km.

Resistance and reactance in series give total impedances which correspond to the distance as the crow flies. Their individual impedances correspond to the two legs of the journey. So if AB represents a resistance of 4 ohms and BC a reactance of 3 ohms the overall reactance is 5 ohms (b).

DIRECTIONAL EFFECTS

Is BC a capacitive reactance or an inductive one? Or doesn't it matter? It matters, because of the way inductive and capacitance

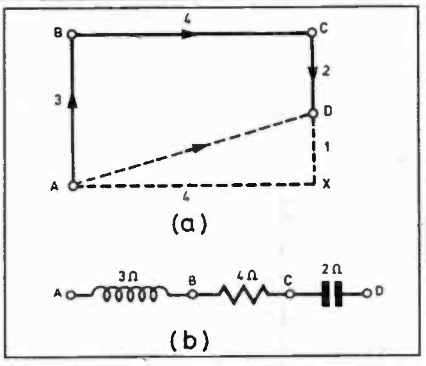


Fig. 3. A more complex circuit can be simplified by geometry. (a) The journey from A to B to C to D covers the "crow's flight" distance AD. This can be calculated from AX and DX. (b) Circuit equivalent to (a).

reactances tend to cancel one another. This affects the direction of the short leg of our journey. If the reactance had been 3 ohms inductive then the crow's flight path would have been A to D. Still the same overall impedance, but arrived at by a different route, with a track pointing in a different direction.

That's the point. Impedances don't just have magnitude (so many ohms). They have direction, too. The situation is made manageable by adopting two conventions:

1. Reactance is always at right angles to resistance.
2. Inductive reactance is "up", capacitive "down".

For a simple two-element circuit like Fig. 2b the net impedance can be found either by drawing a diagram and measuring AC or AD, or by making use of the fact that the three points A, B, C (or A, B, D) are at the corners of a right-angled triangle. The net impedance is given by the length of its hypotenuse. So, making use of Pythagoras' Theorem, the net impedance is obtained by squaring each individual impedance, adding the results then taking the square root of the total.

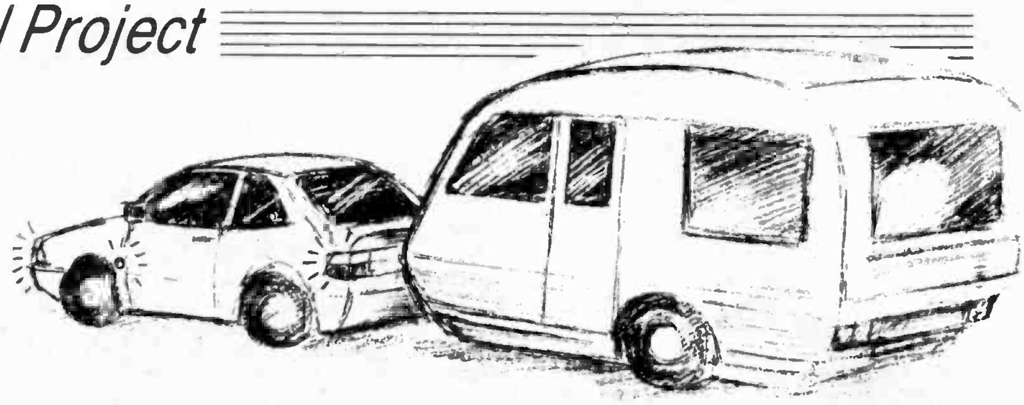
COMPLEX CIRCUITS

Where all three kinds of element (resistance, inductance, capacitance) are present, things begin to look complicated. Don't worry. There's a way of uncomplicating them. Fig. 3 maps a journey with three legs. The first AB is pointed upwards (inductive reactance), the second, BC is horizontal (resistance) and the third pointed down (capacitive reactance).

If you try to find AD from the four-sided figure ABCD life is a bit difficult. But AD is also the hypotenuse of triangle ADX. Since AX = BC and DX = AB–CD the answer is obtained almost as easily as before.

Electrical engineers have a way of dealing with complex impedances without drawing diagrams like Fig. 3. It's called (among other things) 'j' notation and it's very useful for designing circuits. But that's a topic for another article.

Constructional Project



LIGHT WORK

T.R. de VAUX-BALBIRNIE

A handy aid for checking trailer or caravan lights.

A CONVENIENT way of testing the operation of rear lights on a caravan or trailer is made "Light Work" with this low cost project. It will thus be found useful for any reader who owns a caravan, boat trailer, horse box, etc.

For safety reasons, it is essential to check the rear lights (brake lights, flashing indicators and tail lights plus fog lights, where fitted) before setting out on a journey. This check often takes the form of a member of the family standing behind and shouting out that all is well or not as the driver operates the lights in turn.

When doing this check alone, the brake lights will be found to present the greatest problem since pressure needs to be applied to the brake pedal for the check to be made. Sometimes the only way of doing this is to place a heavy object on the pedal while a trip is taken to the rear of the outfit to look at the lights. With Light Work things are made easier because all lamps are checked from the driver's seat without assistance.

ILLUMINATING

In use, the device is attached temporarily to one of the rear light clusters. The unit is switched on and each lamp operated in turn. If it is working, a shrill tone will be heard from a sounder.

Having checked one set of lights, the procedure is repeated with those on the other side. Deaf readers could connect a small bulb in a lamp holder (a 6V 0·06A M.E.S bulb would be suitable) on a long piece of twin wire in place of the audible warning device.

The unit is built in a small plastic box housing the circuit panel and battery. The audible warning device is mounted on the back (see photograph).

The box is fitted with some means of attachment so that it is held in contact with the light cluster while testing takes place. Holes in the front panel direct the light picked up from the lamps onto the sensitive surfaces of the light sensors mounted on the circuit board.

Since the internal battery is used only occasionally, its life will be almost as long as its shelf life. However, it is suggested that it is replaced at the beginning of each season to prevent the possibility of damage due to leakage.

In some types of rear light cluster, the tail light and brake light operate from a single dual-filament lamp – the light for both functions therefore comes from practically the same position. The flashing indicator lamps are in a different location. That is why, in the this circuit, *two* sensors are used and possibly more will be needed if fog and other lights (such as twin tail lights bulbs) are to be checked. This will involve positioning the light sensors according to the application and this point will be discussed in more detail later.

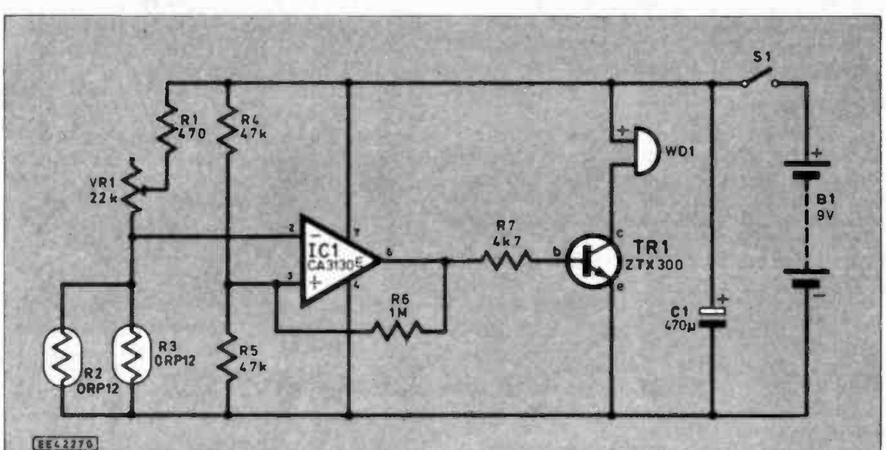


Fig. 1. Complete circuit diagram for the Light Work tester

CIRCUIT DESCRIPTION

The complete circuit diagram for Light Work is shown in Fig. 1. The principle component is operational amplifier, IC1. This is connected as a *voltage comparator.* Thus, if the voltage applied to the non-inverting (+) input, pin 3, exceeds that at the inverting (−) one, pin 2, the device switches on with the output (pin 6) high (positive supply voltage). In other cases, the output is low i.e. off.

The voltage applied to IC1 pin 3 is fixed by the potential divider action of resistors R4 and R5. Since these are equal in value, the voltage here will be one-half that of the supply – that is, 4·5V approximately. The purpose of resistor R6 will be explained presently.

The voltage applied to IC1 pin 2 depends on the potential divider consisting of fixed resistor R1 in conjunction with preset potentiometer VR1 (connected as a variable resistor) in the upper section together with light-dependent resistors (l.d.r.s) R2 and R3 and possibly others, connected in parallel in the lower section. The l.d.r.s act as light sensors and their positions on the circuit board will be such that they pick up light from the various lamps when the unit is in position. Should any light-dependent resistor receive extra light, its resistance will fall and with it the voltage applied to IC1 pin 2.

With the l.d.r.s dimly illuminated and with VR1 correctly adjusted, the voltage at pin 2 will exceed that at pin 3 and the op.amp will be off. No current will enter the base of transistor TR1 so the audible warning device (solid-state buzzer), WD1 will remain off.

When light shines on any light-dependent resistor, the voltage appearing at pin 2 will fall below that at pin 3 and the op.amp will switch on. Pin 6 now goes high and current enters TR1 base through current-limiting resistor, R7. Collector current then flows and the buzzer sounds.

Resistor R6 applies a little positive feedback. This improves the switching action so that the buzzer makes sharp transitions from off to on and vice-versa.

CHOICE OF BUZZER

Small, cheap buzzers will possibly not be heard from the driving position and it is best to buy a *piezoelectric sounder* of the type specified in the components list. This can easily be heard even when there is quite a lot of other noise around. Note that it is important for the buzzer to be of a type which *does not* require external drive circuitry. If it is described as being capable of operating from a 6V or 9V d.c. supply, it should be suitable.

Before beginning construction work, a decision needs to be taken as to the number and position of the lights to be monitored. This will possibly affect the size of the box needed. The distance between the brightest areas of illumination needs to be measured so that the l.d.r.s may be correctly positioned to align with these when the unit is in position (see photograph).

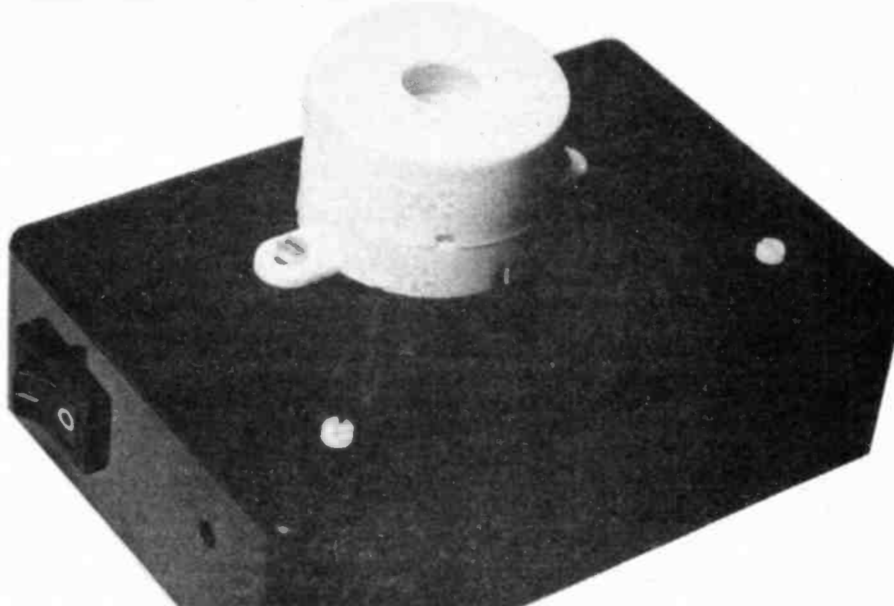
The unit has been tested with three sensors but there is no reason why further ones should not be added as required. If some lamps are close to one another, it may be possible to use slot-shaped holes so that two lamps having different functions share the same l.d.r.

CONSTRUCTION

The prototype unit is built on a circuit panel made from a piece of 0·1in. matrix stripboard, size 12 strips x 35 holes. The topside component layout and details of breaks required in the copper tracks on the reverse side are shown in Fig. 2.

It will be noted that the l.d.r.s are mounted on two "rails" formed by strips *H* and *L*. The l.d.r.s – and any additional ones may be soldered to these strips in any position to suit the lighting unit.

In some cases, it will be necessary to extend the end leads on l.d.r.s so that they may be mounted in a position displaced from the circuit panel. If so, use fairly substantial single-strand insulated wire (say, 20s.w.g.) so that they will take up their new positions without further support.



The warning transducer mounted on the back of the completed unit. Holes in the front panel direct light onto the surfaces of the light sensors.

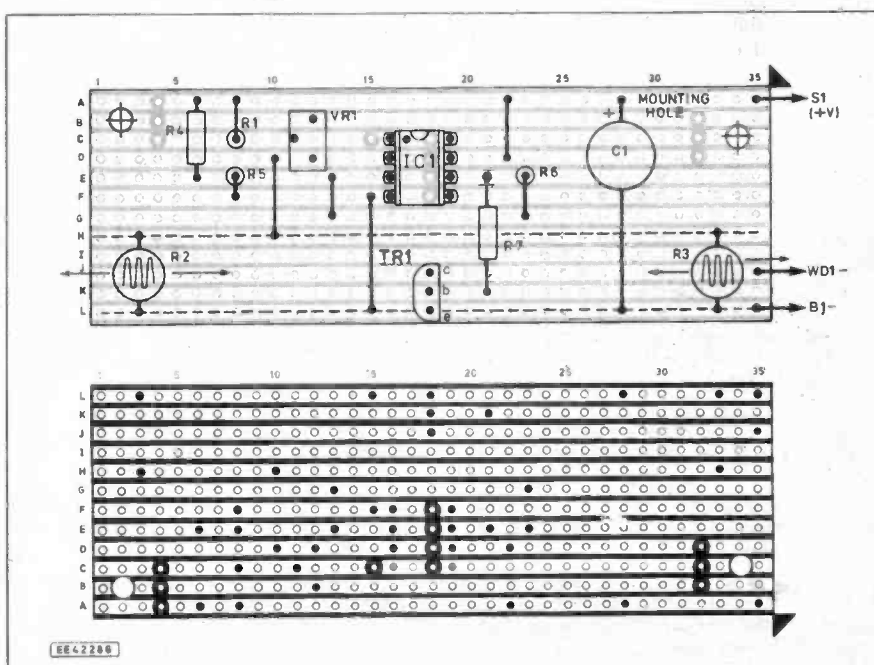
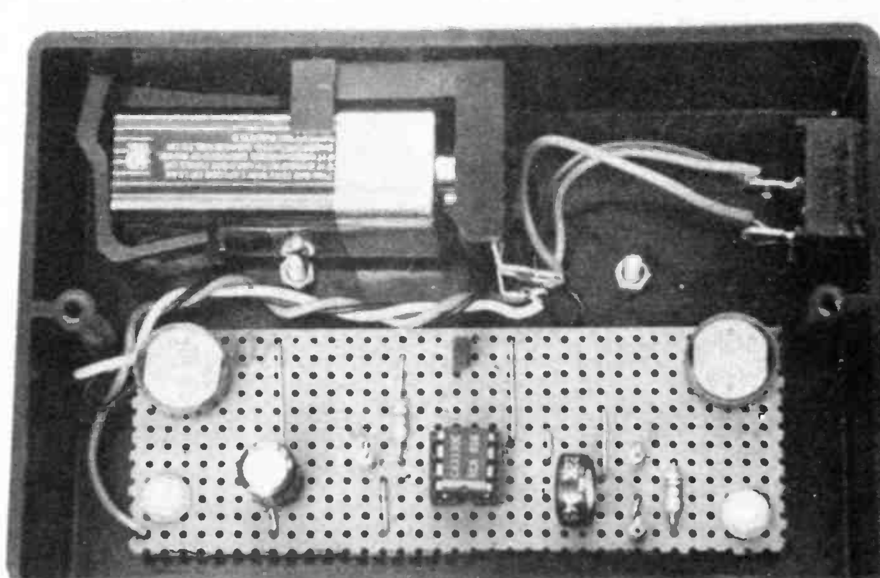


Fig. 2. Stripboard component layout and details of breaks required in the underside copper tracks. Layout of components inside the box is shown below.



COMPONENTS

Resistors
R1 470
R2, R3 ORP12 light dependent resistor (2 or 3 off – see text)
R4, R5 47k (2 off)
R6 1M
R7 4k7
All 0·25W 5% carbon, except R2, R3.

See SHOP TALK Page

Potentiometer
VR1 22k carbon preset, lin.

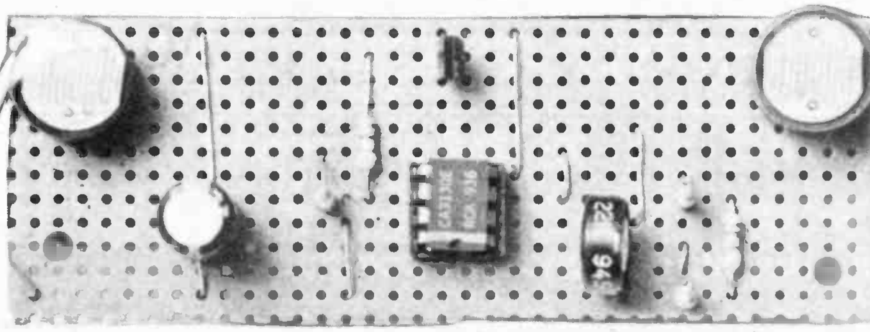
Capacitor
C1 470µ radial elect. 16V

Semiconductors
TR1 ZTX300 *npn* silicon transistor
IC1 CA3130E op.amp

Miscellaneous
S1 Miniature s.p.s.t. toggle or rocker switch
B1 9V PP3 battery and battery holder
WD1 High-power audible warning device – 3kHz. 6V to 9V d.c. operation.

Stripboard 0·1in. matrix, size 12 strips x 35 holes (see text); case, ABS plastic, size 114mm x 76mm x 38mm; 8-pin d.i.l. socket; stranded wire; solder; materials for attaching the unit (see text); small fixings, etc.

Approx cost guidance only **£12**



The completed circuit board showing the mountings of the radial capacitor and l.d.r.s.

Note that capacitor C1 is specified as a *radial lead* component. This helps to keep the "rails" clear of components to allow for correct l.d.r. positioning. An *axial* lead capacitor would possibly get in the way.

Begin construction by cutting the circuit panel to size, breaking copper tracks as indicated, drilling the two small mounting holes and making all inter-strip links. Check carefully for errors and follow by soldering the on-board components into position. Note that the l.d.r.s are soldered approximately 4mm clear of the circuit panel on short "stalks".

Take care when soldering capacitor C1 since it is a polarized component and so must be connected the correct way round (the negative end is marked on the body). Do not insert IC1 into its socket at this stage.

Solder 10cm pieces of light-duty stranded connecting wire to strips *A* and *L* on the right-hand side of the circuit panel and solder the negative audible warning device wire to strip *J*. Adjust VR1 sliding contact fully *clockwise*.

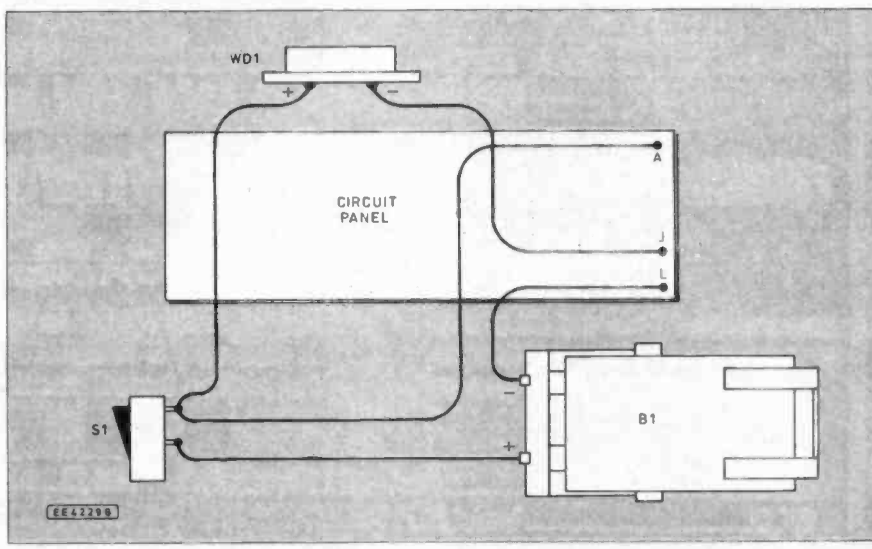


Fig. 3. Interwiring from the circuit board to battery holder, switch and warning buzzer.

Prepare the box by drilling mounting holes in the base to correspond with those already made in the circuit board. Drill holes for the audible warning device, battery holder and for switch mounting.

Measure the positions of the l.d.r.s and drill holes in the lid 6mm in diameter to correspond with these positions. Drill a small hole in the side of the box so that VR1 may be adjusted through it using a small screwdriver.

Attach the circuit panel to the base of the box using short stand-off insulators to provide a clearance of 2mm. Referring to Fig. 3, mount all remaining components and complete the interwiring shortening any wires as necessary.

Check that there is a clear path for light to pass to the sensitive surfaces of the l.d.r.s and make any adjustments as necessary. Inserts IC1 into its socket with the correct orientation, place the battery in its holder and attach the lid.

SETTING-UP AND TESTING

Do a rough check by switching on the unit and pointing the l.d.r. holes toward bright light. The buzzer should sound. If not, adjust VR1 sliding contact *anti-clockwise* until it does. Cover the l.d.r. holes with the fingers and check that the buzzer stops sounding sharply and reliably.

Accurate adjustment may only be carried out with the unit in position but it helps to make an approximate adjustment beforehand. To do this, adjust VR1 so that the buzzer *just* remains off with the unit exposed to dim room lighting.

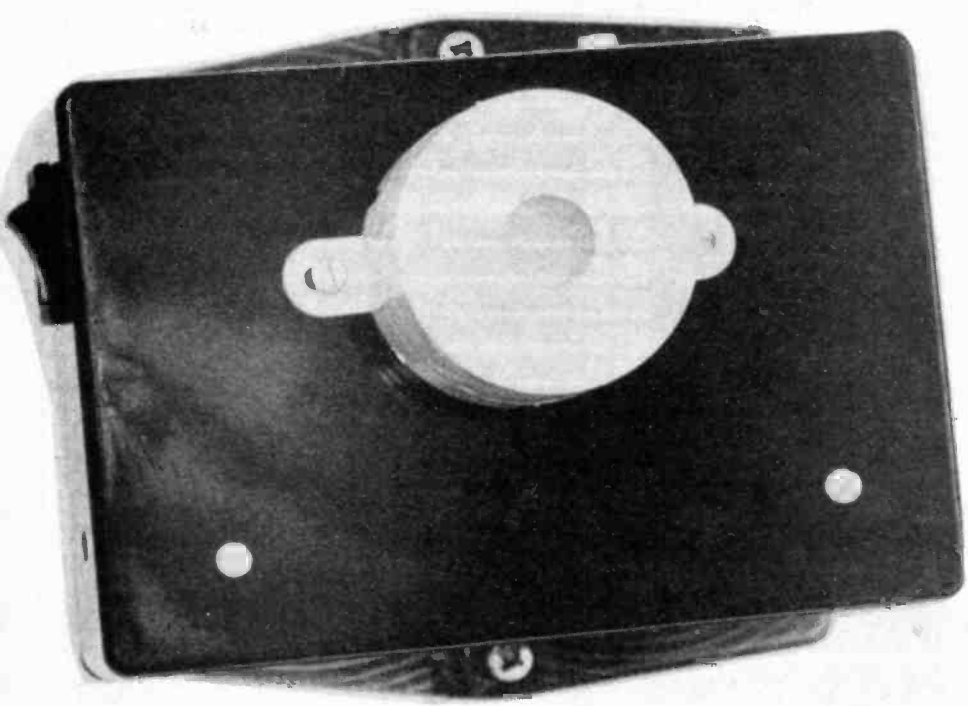
The way in which the unit is attached to the light cluster will depend on the type. It may be that rubber suckers provide the best solution. Another idea is to use small pieces of Velcro strip. However, four blobs of Blu-Tak were found sufficient in the prototype.

Whichever method is used the important point is that, when in operation, the unit is held with the working surface pressed close to the lighting cluster. This will ensure that as little extraneous light as possible enters the box which could possibly result in false operation.

The bright lights – i.e. brake lights and flashing indicators will present no problem. However, the tail lights are much dimmer and to take account of these, adjustment to VR1 is fairly critical.

It may sometimes be necessary to provide a circle of black velvet or similar material around the l.d.r. holes – perhaps where the shape of the lighting unit prevents the case from making good contact with it. However, there were no such problems in the prototype unit.

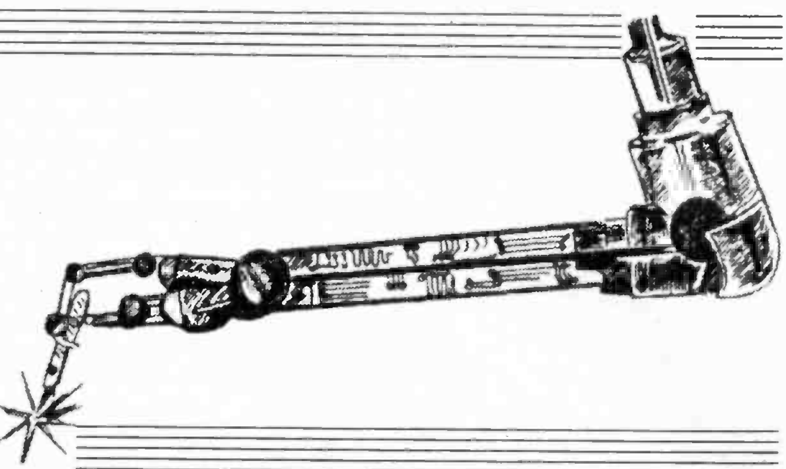
With Light Work you can forget the chore of lamp-checking and concentrate on your holiday! □



The completed Light Work mounted on a light cluster. Method of mounting can be by rubber suckers or Velcro strips.

Regular Clinic

CIRCUIT SURGERY



MIKE TOOLEY B.A.

Welcome once again to* Circuit Surgery, *our regular clinic devoted to readers' problems. This month we turn our attention to an inexpensive yet versatile power amplifier module which can be configured for both single-ended and bridge operation. We begin with two interesting quickies from my postbag:

Addressing the public

Jim Scott writes from Oxford to ask for some information concerning a business venture. Jim writes:

"I have an interest in sound and public address and am now thinking about starting my own business. Can you recommend a source of information which is not too technical but which describes the sort of equipment that I would need to get going? There seems to be a large number of books on audio and hi-fi reproduction but none of them seems to deal with public address systems."

Well Jim, there's one that you've missed; *Public Address Systems* by Vivian Capel (published by Focal Press, ISBN 0-7506-0732-7). This book gives the subject a thorough "going over" and it includes a description of the sort of equipment that you will need to start your business.

The author is a freelance audio consultant and he has a particular interest in public address systems. His book will give you plenty of ideas and it will also help you to avoid a few of the pitfalls too!

How long will they last?

"How many times can you charge and re-charge a nickel-cadmium battery?" writes ***Normal Phillips*** from South Humberside.

Well, Norman, there is no "hard and fast" answer to this question – it all depends on how you use them! Most manufacturers claim as many as 700 charge/recharge cycles for AA, D or C size batteries and and a minimum of 400 cycles for a PP3 battery. These figures do, however, apply to "normal use" (i.e., a regular charge/discharge cycle at the manufacturer's recommended rates).

All nickel cadmium batteries become less efficient towards the end of their working lives as their charge retention characteristics deteriorate. However, provided you treat them with care, they should give you several years of trouble-free operation. Surprisingly, the key to getting the best out of nickel cadmium batteries seems to be regular use.

At this point, perhaps I should point out that the trusty Toshiba laptop PC on which I am producing this article has been in regular use (almost daily) for over two years using the *original* nickel cadmium battery pack. The computer is used on average for about three hours each day and its battery pack is re-charged every night. Over the two year period, I have noticed no deterioration in charge retention!

Budget Power Amplifier

N. Thomas writes from Shrewsbury with a "short and sweet" query:

"I need an affordable guitar practice amplifier. It should be easy to build using common components. Can you provide me with a circuit, please?"

Several other readers expressed interest in the compact audio amplifier which I described in an earlier *Surgery* but have asked for details of something a little more powerful. With this in mind, I set about producing a simple power amplifier module that can be used in a variety of applications yet could be built for under £5 (excluding case and hardware). I based the design on a single operational amplifier and a complementary Darlington output stage.

The complete circuit diagram of the Budget Power Amplifier module is shown in Fig.1. IC1 is operated in differential mode with a fixed voltage gain of 100. The Darlington transistors, TR1 and TR2, form the complementary output stage. When compared with conventional transistors these devices exhibit an exceptionally high value of current gain.

The bias for the output stage is derived from the chain of four diodes, D1 to D4. This circuit is simple yet effective and has the advantage that no bias adjustment is required. A current of about 0·6mA flows in the diode chain which is just sufficient to bias the diodes into conduction and ensure that the output transistors are at the threshold of conduction.

The pin connections for TR1 and TR2 are shown in Fig.2. Almost any complementary pair of plastic power Darlington transistors can be used in place of the TIP121 and TIP126 used in the prototype however they *must* be mounted on adequate heatsinks. Ideally they should be rated at 4 deg.C per Watt, or better. Note that I prefer not to use insulating washers as heat transfer is improved when the metal tab of a TO220 package is in direct contact with a heatsink surface. Unfortunately, this requires individual heatsinks for each device as their collectors are internally connected to the metal tab.

Construction is extremely simple and straightforward. The entire circuit can be built on a small piece of matrix board with connections brought out to terminal pins. It

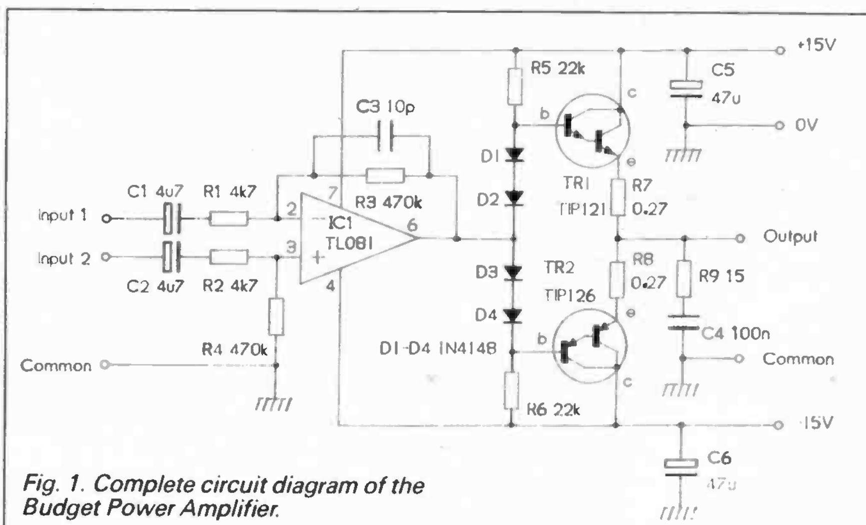


Fig. 1. Complete circuit diagram of the Budget Power Amplifier.

BUDGET POWER AMPLIFIER SPECIFICATIONS

Output power (single-ended):	5W r.m.s. into 8 ohm at 1kHz
	8W r.m.s. into 4 ohm at 1kHz
(bridge):	20W r.m.s. into 8 ohm at 1kHz
	30W r.m.s. into 4 ohm at 1kHz
Voltage gain:	100
Input signal (for full output):	less than 250mV pk-pk
Input impedance:	4·7 kilohms
Frequency response:	10Hz to 30kHz at –3dB
Distortion:	less than 0·1 per cent at 1W output
Power supply voltage:	+ 15V and –15V d.c. (max.)
Power supply current:	0·6A single-ended or 1·2A bridge (full-output), 20mA (quiescent)

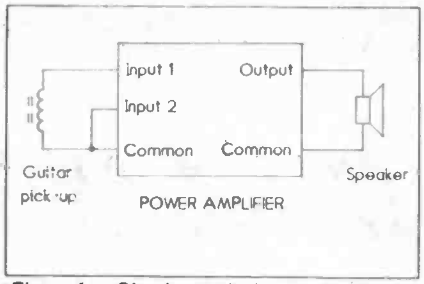


Fig. 4. Single-ended configuration (5W output).

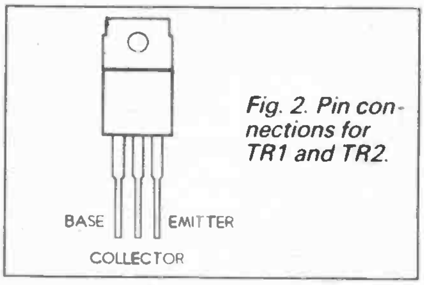


Fig. 2. Pin connections for TR1 and TR2.

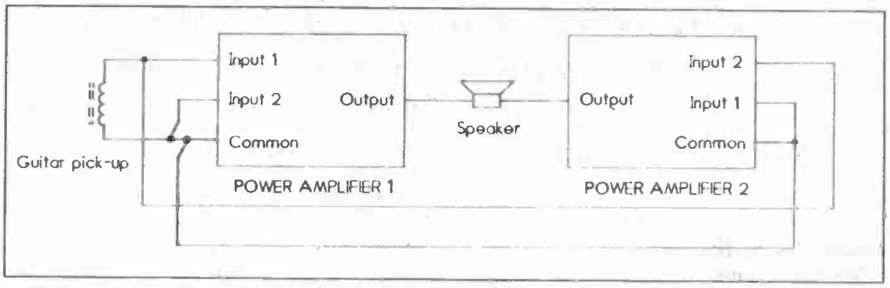


Fig. 5. Two amplifiers in a bridge configuration (20W output).

is, however, advisable to mount IC1 in a low-profile d.i.l. socket so that it can be easily removed and replaced.

You should also ensure that the four diodes (D1 to D4) are mounted in close proximity to their respective output transistors (i.e., D1 and D2 should be mounted close to TR1 whilst D3 and D4 should be placed close to TR2). The diodes provide thermal feedback and this can be achieved either by bonding them to the heatsink using a small amount of epoxy adhesive or by soldering them as close to the transistor pins as possible (in which case heat will be conducted from the pins to the diodes through the soldered connections).

Power supply

A suitable power supply for the amplifier is shown in Fig.3. This circuit produces unregulated outputs of + 15V and –15V at up to about 1·2A (depending upon the transformer rating).

If you intend to make use of a stereo or bridge output configuration you will need two power amplifier modules and a 50VA transformer. If, on the other hand, you require a mono or single-ended amplifier (as in the case of a guitar practice amplifier) a transformer of 25VA will be adequate.

Configuring the power amplifier

The power amplifier module can be configured for either single-ended (mono or stereo) operation or for bridge operation.

The single-ended configuration required for a guitar practice amplifier is shown in Fig. 4. Note that "Input 2" is linked to "Common". The input source (in this case a guitar pick-up) is connected between "Input 1" and "Common". The circuit delivers up to about 5W r.m.s. into a 8 ohm load at 1kHz with a supply rail of ± 15V.

The bridge configuration is shown in Fig. 5. The input signal is applied to "Input 1" of one power amplifier module and "Input 2" of the other. The unused input terminals of both modules are linked to "Common". The most important thing to note here is that the loudspeaker is connected between the two "Output" terminals (neither end of the speaker is connected to "Common"). The bridge configuration can deliver up to 20W r.m.s. output into 8 ohms, again from a ± 15V supply.

Next month: Information on component substitution together with a list of "preferred" semiconductor devices. This will be particularly useful for those of you who may from time to time have experienced difficulty obtaining the parts specified in EPE articles. We will also have details of a "Budget Pre-amplifier" (pre-amp, mixer and tone control) which can be used with the budget power amplifier described this month.

In the meantime, if you have any comments or suggestions for inclusion in *Circuit Surgery*, please drop me a line at: Faculty of Technology, Brooklands College, Heath Road, Weybridge, Surrey, KT13 8TT. Please note that I cannot undertake to reply to individual queries however I will do my best to answer all questions from readers through the medium of this column.

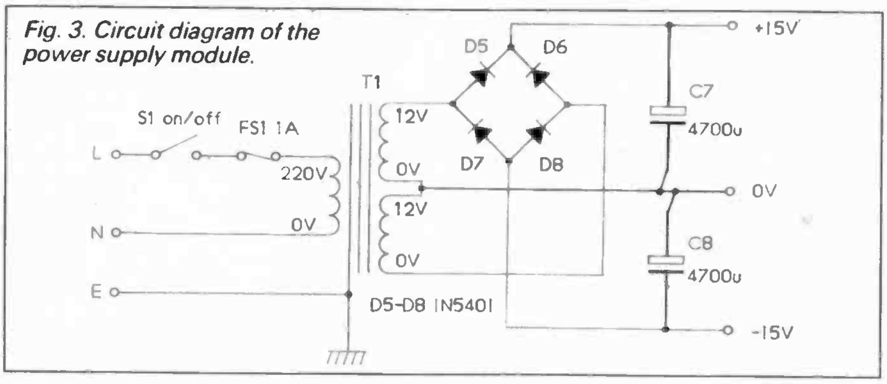


Fig. 3. Circuit diagram of the power supply module.

COMPONENTS

Budget Power Amplifier

Resistors

R1, R2	4k7 (2 off)
R3, R4	470k (2 off)
R5, R6	22k (2 off)
R7, R8	0Ω27 0·5W (2 off)
R9	15

All fixed resistors are 0·25W, 5% except R7 and R8

Capacitors

C1, C2	4μ7 axial elect. 25V (2 off)
C3	10p ceramic
C4	100n polyester
C5, C6	47μ axial elect. 25V (2 off)

Semiconductors

D1 to D4	1N4148 diode (4 off)
TR1	TIP121 *npn* Darlington
TR2	TIP126 *pnp* Darlington
IC1	TL081 op.amp

Miscellaneous

Matrix board (approx. 120mm x 100mm); terminal pins (8 required); heatsinks – see text

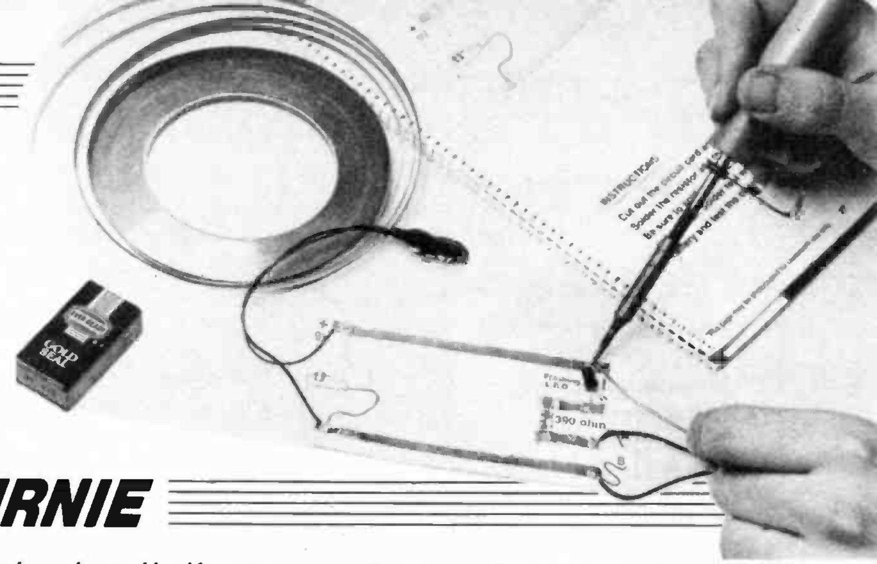
Power Supply Module

C7, C8	4700μ elect. capacitor 25V (2 off)
T1	25 or 50VA mains transformer (see text) with two 12V secondary windings rated at 1A or 2A min. respectively
FS1	1A 20mm quick-blow fuse
S1	S.P.S.T. miniature toggle switch (rated for mains operation)
D5, to D8	1N5401 3A 100p.i.v. diode (4 off)

Terminal pins (6 required)

Approx cost guidance only **£18**

MAKING TRACKS



T. R. de VAUX BALBIRNIE

Report on a new circuit-building method for Technology students.

THE Technology National Curriculum is all about *thinking, designing, constructing and evaluating*. Electronics and other technologies are involved in the complete design process now being taught in schools.

No student is expected to understand *how* a thyristor or an l.e.d. works – only what it does and how it may be used with other components to make a useful system. At Key Stage 4 (students aged 14 to 16) this will involve writing a specification, drawing a circuit diagram and building a trial circuit. There will then follow testing, checking performance against the specification and modifying the design as necessary.

THE RIGHT TRACK

At Key Stage 3 (pupils aged 11 to 13) students will already have had some experience of constructing simple circuits at primary school. They will be encouraged to build on this knowledge and to be introduced to the design process in a gentle way. Over the three-year period this method of working will become firmly established ready for the demands of Key Stage 4.

The chief problem is the difficulty students find in translating even a simple circuit diagram into a practical layout. It is therefore easy for them to become disillusioned when using traditional methods. There is a body of opinion which suggests that the easier this part of the process is made, the better the students will ultimately perform at Key Stage 4.

The *Tracktronics* system developed by Richard Taylor (General Adviser for Technology in Northumberland) and Will Toner (Head of Technology, South Hunsley School, Humberside) aims to address the above problem. The authors identified the need for a new system of circuit-building in 1986 – at this time they were working together as advisory support teachers in Humberside.

WHAT A COMMOTION

After trying out the new system in schools and following good reports, the authors approached Commotion (the company name came about from *Computer Aided Motion*) in 1990. Commotion assess "good ideas" passing through their hands and provide funding when they judge the scheme to be marketable and fits their target age group of 5 to 13 years.

Such was the decision to pursue *Tracktronics*. Commotion proceeded to publish a trial run of 1600 books to go with the course in November, 1992. These have now sold out following a great response from schools. The second edition was printed earlier this year.

The Tracktronics idea is simple enough. The circuit diagram is obtained from photocopy masters – *circuit cards* – in the Teacher's Book. This shows the circuit as it appears – a resistor looking like a resistor and so on. There is the occasional inconsistency where a circuit symbol is used instead but this does not matter much.

Sticky-backed copper tape – or *track* – 5 mm wide is now applied to the lines – scissors being adequate to cut it to size. Gaps are left where components are to be inserted and after bending the end leads, these are soldered into position (see photograph).

CURRENT PATH

At all times students clearly see the current path. At the same time they are using real components. They also develop important *key skills* such as soldering.

The Tracktronics method is rather like a p.c.b. with both components and copper track on the same side of the "board" – a simple form of "surface mounting", in fact. Not only are the components visible throughout but there is no "mirror imaging" and hence a more logical layout in the minds of the students.

Although components are soldered into position, they may be removed easily and with care are capable of being used many times. On the other hand, the circuits are permanent enough to be attached to cardboard or wood and used indefinitely if required. The copper track, of course, must be regarded as single-use material.

As well as Circuit Cards, there are Circuit Planner Sheets where the new-found knowledge is applied. Here the circuit is given in the form of conventional symbols and the student is directed towards drawing out his or her own copper track layout. This is done in pencil on a printed grid.

TO THE TEST

I tried the system using a soldering iron clumsily as a beginner might do. I wanted to check the method, to see if the copper strip would remain stuck to the work and if solder "took" well to the track material. Everything went well. I did find it difficult starting to peel the paper backing from the track. Probably young fingers would find it easier especially when they acquired the knack.

The stock roll of track is not something which should be given to students or it might end up in a mess. It would be better for the teacher to issue it in short lengths.

It is thought that the course could prove heavy on PP3 batteries as recommended. However, it would be a simple matter to use AA or larger size batteries in suitable packs fitted with PP3-type connectors. This would prove cheaper in the long run.

The Tracktronics construction method is limited to simple circuits appropriate to Key Stage 3. However, by instilling confidence, the use of prototype boards and eventually p.c.b. methods for more complex circuits will follow naturally and the link between the methods readily appreciated.

SUPPORT

Commotion provides support for the Tracktronics course in the form of two books – a Pupil Text (£7.95) and a Teacher's Guide (£12.95). Both are A4 size, attractive-looking and spiral-bound to lie flat on the bench. These are available separately as are 33m rolls of copper track (£4.64 including VAT). Components for each unit are available as 10-pupil sets in "Trackpacks" but, of course, basic components may also be purchased from other suppliers.

The Teacher's Guide provides a lot of useful information which would help the non-specialist called upon to teach the course. The layout of the Pupil's Book is clear and should suit a wide ability range. There is plenty of material which will stretch the more-able with further development work. At the same time, the less-able will be motivated. The five units covered are switches, l.e.d.'s, flashing l.e.d.'s, thyristors and transistors.

The Commotion catalogue containing the full Tracktronics range is available from: Commotion, Dept EPE, Redburn House, Stockingswater Lane, Enfield EN3 7BR.

There is also a telephone hot line on 081-804-1378

FOX REPORT

by Barry Fox

BT – NO MORE!

I do genuinely wish I did not have to write more criticism of British Telecom. But once again the company has proved that its senior management remains wildly oblivious to the real life needs of computer users. In an age of IT, how long can this nonsense go on?

BT's Telecom Gold electronic mail service was launched ten years ago with software bought in from US company Dialcom. It was very unfriendly and has remained that way. BT has always argued that once Gold had been launched, it could not radically change the software.

After ten years Gold still throws up prompts like "call" and "pad" which could so easily have been replaced with more helpful requests. And it is still completely unforgiving of any keying error, like "sned" for "send", offering users no help, just error messages.

So only those who have grown up with Gold want to use it. Potential new customers take one look and stick with fax. Some companies have forgotten they even have the service, and pay through the nose for Gold to store old messages it has filed away without telling the subscriber.

MAILBOX

Small wonder that BT admits Telecom Gold is steadily losing customers, some of which have opted out when they finally checked their bills. So BT is replacing Gold with a new service called Mailbox.

You would think that BT would have learned something from the mistakes made with Gold, and the mistakes made on the disastrous launches and relaunches of its two other on-line services, Electronic Yellow Pages and Phonebase (the Directory Enquiries service). But no, BT has blown it again.

Although Mailbox has some very good features, the new service risks getting a bad name right from the start because the user-software is awkward to install and set up. Although big companies, which employ a computer department, will be able to shield staff users from the problems of setting up Mailbox, small businesses and individuals will have to do it themselves. Unless they are computer-literate, there is a good chance they will simply give up and continue to send faxes instead of electronic mail messages.

It is already too late to stop bad first impressions. BT has since last year been refusing to sell a Gold subscription to the few people who might ask for one, and will by now have started on a campaign encouraging existing subscribers to switch to Mailbox. BT has already printed publicity material which sells the idea of Mailbox, albeit with a very confusing mish mash of leaflets for all manner of different services.

The key point is that Mailbox uses the X-400 world standard for electronic messaging, set by the CCITT, the International Telegraph and Telephone Consultative Committee. X-400 defines a common format for electronic messages, so that any telephone network can act as a common highway for messages coming from all types of computer, whether mainframe, mini or PC.

Any subscriber to an X-400 system gets an individual address name so that subscribers on X-400 services around the world can send each other messages. This is not possible with the Telecom Gold service, which locks users into sending messages only to other Gold or Dialcom subscribers.

The software needed to convert a message into X-400 standard format is complex, so the conversion is done by BT's computers. The subscriber with a desktop PC loads BT's Mailbox software which automatically dials the number of BT's host computer and sends it the subscriber's message. BT's host computer then converts the message into X-400 format and directs it down national or international telephone lines, and into the distant X-400 network from which the distant subscriber can retrieve it.

The message can be anything which a computer puts out, text, graphics or spreadsheet data. The X-400 standard just wraps the computer's data in a standard package which the receiving computer unwraps. The same message can also be sent to any telex address or to any fax number. Whereas Telecom Gold handles data at a maximum speed of 2·4 Kbits, Mailbox is now being tested at 9·6Kbits.

COST

Existing Telecom Gold users can switch over to the new service free, but new subscribers will pay a one-off fee of £100 to join and get the Mailbox software for their PC. Whereas Telecom Gold users pay a monthly subscription of £7.15, plus the cost of using the service, Mailbox subscribers will pay seven per cent less for using the service, but a minimum monthly charge of £25 instead of a monthly fee. This will favour heavy users, but be more expensive for casual users.

One hidden benefit is that Mailbox will no longer play Telecom Gold's sneaky trick of transferring old messages into deep storage, and then charging the subscriber for storage, without any warning. Mailbox will simply throw away old messages because the PC software automatically downloads all messages for storage, free, in the subscriber's PC.

BT believes this will make it easier for businesses round the world to communicate and employees "telework" from home. It could indeed. All other things being equal, Mailbox represents a welcome move towards replacing the wasteful use of fax with electronic mail. But all other things are not equal.

CLUMSY

BT already acknowledges that the Mailbox software, bought in from the USA, is clumsy and needs revision. I would say it needs junking, and rewriting from scratch. If just one of BT's highly paid directors had been locked into a room with a PC and told to install Mailbox, it would never have escaped onto the market.

No attempt has been made to follow the modern trend with software, and lead the user through a series of simple questions during the installation process. For instance, instead of prompting the subscriber with a simple question on screen, "Does your telephone dial direct or through a switchboard?" and "What number do you have to dial first to get a line?" the Mailbox software comes preset to put a "9" on the front of every call. So the system will not work first time unless the user's phone happens to be on a switchboard that needs "9" for access.

OUT OF DEPTH

The manual that subscribers get with Mailbox is absurdly bulky. And when I tried to install Mailbox, the installation process failed altogether. BT's helpline quickly got badly out of their depth, giving very dangerous advice.

This, I found out, was because BT had not tried Mailbox with DOS version 6, even after DOS 6 had gone on sale to the public. BT is only now talking to Microsoft about developing a Windows version of Mailbox.

As a result BT is having to warn new users by letter that anyone who tries to run Mailbox under Windows without "detailed information" from BT's Helpdesk, risks corrupting their data. This is because BT discovered too late that Mailbox and Windows both try to use the same area of a PC's memory, and clash.

The advice given on how to solve this (by editing the PC's System.ini file) will make sense only to a computer buff, and contains its own pitfalls. Advice given me by BT on my DOS 6 installation problem produced a scary on-screen message from Microsoft warning of the risk of data corruption. BT's Helpline, which had advised without trying, then had to contact Microsoft for help.

Take my tip. If you are a Telecom Gold subscriber, stick with Gold. If you are thinking of subscribing, wait for Mailbox Version 2.

Audio Amplifier Design, Engineering or Alchemy?

JOHN LINSLEY HOOD

PART 2

The influence of components and circuitry.

WHEN I first tried my hand at electronics, resistors were mostly either wirewound and thumb-sized, or made from pencil thick lumps of fired carbon rod, painted with splodges or stripes to tell the user the approximate order of resistance value the manufacturers hoped their product would offer – provided that it hadn"t been allowed to get hot at any stage in its life, which would, of course, alter its value quite a lot.

PRESISION RESISTORS

If the actual resistance value was important enough to warrant their high cost, one could get "high stability" ("cracked carbon film") resistors, made by coating a ceramic rod with a thin layer of graphite resistive material and then grinding a spiral track through this to increase the track length and resistance value. These were accurate, perhaps to one per cent, but far too dear for everyday use, and only the rich or perfectionist would ever use these in building an audio amp., for which precision of resistance value was only occasionally thought to be particularly vital.

I make this point because we are now in an age in which old style valve amps., which mainly had a pretty nondescript technical performance – and which almost always used a few dozen of these grotty carbon rod resistors, soldered on to tag strips underneath the chassis – are now thought to represent the summit of audio performance from a now lost "golden age", and treated as precious possessions by their lucky owners, while, at the same time it has become fashionable to look with contempt on modern units built with high stability cracked film resistors, now dismissed as cheap and cheerful "carbon film" types.

Yes, metal film types are slightly better, they have a very slightly lower "excess noise" level – not that you would ever be able to detect the difference in any real life hardware – and they have a slightly higher power rating for the same physical size. I use them if they are cheaper and easier to come by, but modern resistors are really very good and reliable, and the old bogies of change in value with applied voltage, and drift in resistance value with time, are happily things of the past, provided that the resistors are used within their ratings. So, other things being equal, quality of sound is not won or lost by the choice of construction between modern resistors.

WHAT ABOUT CAPACITORS?

With capacitors, sadly, we do get into a minefield. A capacitor, in principle, is just a pair of conducting plates, separated by a layer of insulating material. The larger the area, (A), of the plates, the smaller the thickness, (d), of the insulating layer, and the higher its dielectric constant, (k), the larger the value of the capacitance, (C), as defined approximately by the equation:

$$C = kA/11.32d \text{ (pf)},$$

where the dimensions are in centimetres.

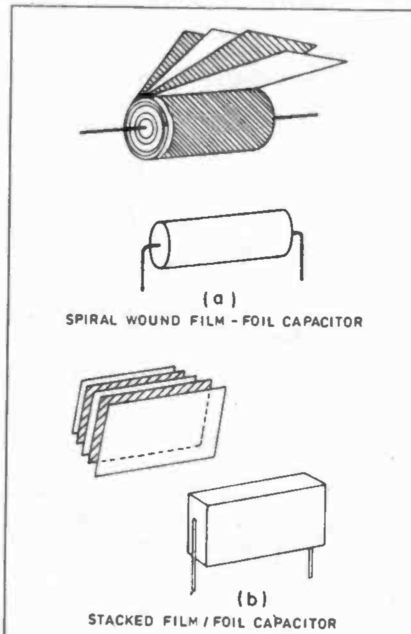


Fig. 1. Capacitor construction types.

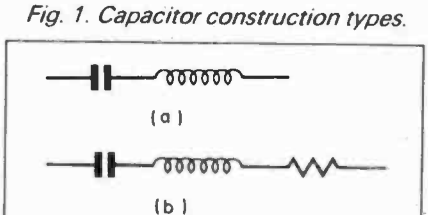


Fig. 2. Equivalent electrical circuit for capacitors.

In practice, there is a measure of choice between the available constructional materials, but all of these have snags.

For example, one can choose a thin plastics film as the insulating "dielectric" layer and one can use a pair of strips of thin metal foil for the two conducting plates.

With even thin gauge dielectric film any sizeable capacitance value is going to need a pretty big area of film and foil, and if the two strips of foil and the two layers of plastics film are wound up into a roll to make it more manageable, as I have sketched in Fig. 1a, the resultant component will then have inductance, leading to the kind of equivalent circuit shown in Fig. 2a. This inductance is minimised by winding the foils so they overlap the dielectric layer at alternate ends, so that when these are joined together by the end contacts it produces a series of "shorted turns".

Similar capacitors made from stacked layers of film and foil, as shown in Fig. 1b, have a similar size, for the same value of capacitance, but with a noticeably lower inductance value, and are, therefore, generally preferable. However, not all of the plastics film dielectric capacitors made in an apparent "flat pack" form are stacked film/foil types – some are just wound layer components made in a flattened form. "Stacked film/foil" types are usually described as this. There are also some low inductance wound types.

If, instead of using strips of foil as the conducting electrodes, the opposing surfaces of the two film layers are given a metallised coating, this will give a more intimate contact between the conductors and the dielectric, which both increases the capacitance and saves some of the space otherwise taken up by the foil strips. Capacitors of this type are more compact, and have a lower internal inductance, but, because the metallised layer is so thin, the capacitor now has also an appreciable series resistance, giving the equivalent circuit shown in Fig. 2b.

DIELECTRIC HYSTERESIS

If we care to look, there are also problems in the behaviour of the plastics dielectric layer itself, due to the fact that when a voltage is applied between its two surfaces it causes an effective charge migration within the material. Not only do these displaced charges not return completely when the applied voltage is removed or reversed: a defect known as "dielectric hysteresis", which makes, among other things, the resul-

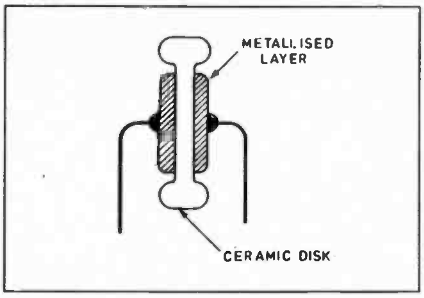


Fig. 3. Ceramic capacitor construction.

tant value of the capacitor frequency dependent: but the migration of the charge, backwards and forwards absorbs energy – a defect known as "dielectric loss", an effect which also appears as a frequency dependent resistance in series with the capacitor.

It is, I think, valuable to preserve a certain measure of cynicism as armour against the "hype" which the salesmen of specialist "audiophile" components – especially capacitors – apply to their expensive (and high profit margin) goods. For example, there is a fairly wide range of variability in, say, polypropylene dielectric film, which can well differ from one film manufacturer to another, and even from batch to batch from the same manufacturer. The seller may not be aware of this, particularly if he has simply re-packaged and re-labelled someone else's goods – so that he can sell them at a higher price.

"Ceramic" capacitors, having the kind of construction I have shown in Fig. 3, take advantage of the fact that some ceramic materials, such as titanium dioxide and barium titanate, can have very high dielectric constants indeed, up to 50,000 or more in some cases, and this allows very large capacitance values to be obtained from relatively small components. Because these devices usually have very low orders of parasitic inductance, they are useful for supply line r.f. decoupling, but, in most other respects, they are not very good, and their capacitance values are usually very strongly temperature dependent.

ELECTROLYTIC

"Electrolytic" capacitors exploit the fact that a very thin oxide layer, with a high dielectric constant, can be formed electrolytically on the surface of an aluminium or a tantalum foil if, during manufacture, an electric current is passed through a suitable electrolyte held in contact with the foil. Usually the oxide layer is formed on the foil before it is assembled in the capacitor, but some electrolyte is retained within the final assembly, as, for example, in the aluminium electrolytic capacitor shown in Fig. 4, so that any crack in the oxide insulating film will be repaired, by electrolytic action, while the capacitor is in use.

Two problems are immediately obvious.

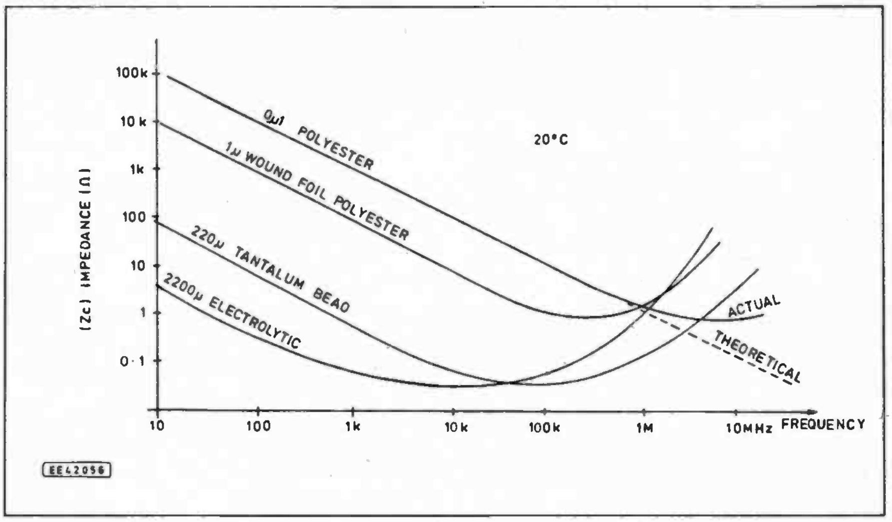


Fig. 5. Actual impedance vs. frequency of real-life capacitors.

The first is that this on-line repair work can only take place if there is a voltage, of correct polarity, present across the capacitor – so they won't self-heal if they are used under zero d.c. voltage conditions: a constant d.c. polarising voltage should always be present. The second obvious problem is that there will then always be a small leakage current through the capacitor, and since this leakage current is quite random in its nature, it will cause circuit noise, which makes them unsuitable for use in any low level audio signal line.

Other difficulties are that electrolytic capacitors have a high value of dielectric loss, and, because of the less than perfect conductivity of the electrolyte, they have a relatively high (and frequency, voltage, and temperature dependent) value of series resistance. Apart from their occasional proneness to catastrophic failure, miniature tantalum bead capacitors do offer a convenient means of obtaining a large capacitance in a small package, with a relatively low level of leakage current.

The miniature "solid aluminium" electrolytics offer a comparably good and somewhat less expensive alternative to tantalum, but all electrolytics are a lot less good for audio use than plastic film dielectric components, and some of these are better than others.

IDEAL CAPACITOR

The ideal capacitor has an impedance (Z_c) which is related to its capacitance value (C) and the working frequency (f) by the equation:

$$Z_c = 1/2\pi fC.$$

and this should, on a log scale, give a straight line graph of impedance decreasing with frequency. Unfortunately, the shortcomings of capacitors, because of their internal inductance and resistance, lead to the kind of relationship I have shown for different capacitor types in Fig. 5.

CAPACITOR USE

There are three main applications for capacitors in audio circuitry. The first of these is as power supply reservoir capacitors, where, in simple p.s.u. designs of the kind I have shown in Fig. 6, the bigger the capacitance value the better. These will invariably, in solid state amps., be electrolytic types, with values, in the more "butch" designs, up to 100,000μF, with massive transformers to boot.

The amplifier designers hope, thereby, to be able to drive large amounts of audio current into the speakers at low frequencies, thereby providing a very "punchy" bass. Of course, if one of the output transistors goes short-circuit in use, the reservoir capacitors will also be able to drive massive amounts of d.c. into the speaker speech coils, for as long as it takes to smoke them out.

I prefer to use a current limited stabilised power supply, which is a safer, and more elegant, way of providing a low output impedance at bass frequencies. Undoubtedly the type of p.s.u. used with an amplifier has an effect on its sound quality, though mainly at its "bass" end.

The second use of capacitors is as a supply line "bypass", or "decoupling" capacitor, of which the main purpose is to try to provide a zero impedance, a.c. ripple free, power supply line, to help in preventing electrical "rubbish" on the supply rails from getting in to the signal line. However, as shown in Fig. 5, no capacitor ever does offer a zero a.c. impedance, even at high frequencies, but a lower a.c. bypass impedance can be obtained if several capacitors are connected in parallel, as shown in Fig. 7. In this case, the ratio of capacitance of each to the others should be, ideally, between 10:1 and 100:1, say 470μ, 4μ7 and 47n. Once again, it is

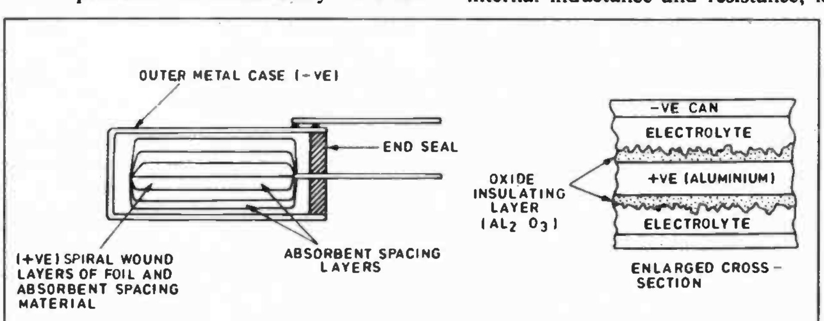


Fig. 4. Aluminium electrolytic capacitor (radial lead type).

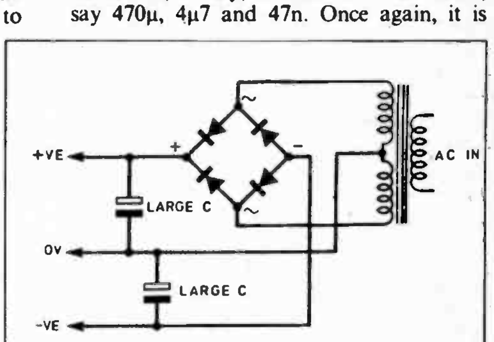


Fig. 6. Simple capacitor/rectifier p.s.u.

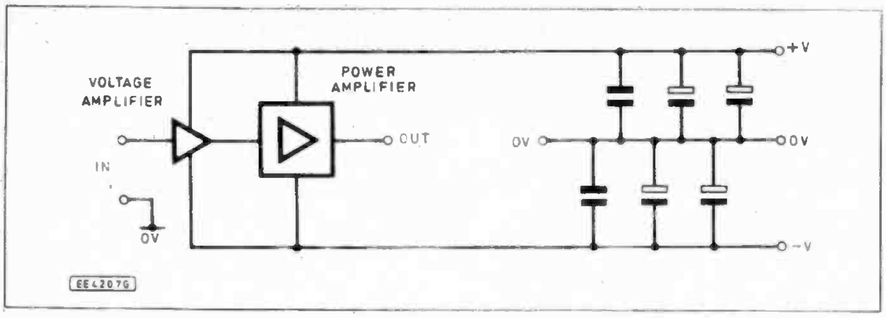


Fig. 7. Lowering the a.c. bypass impedance

better design to so organise the circuitry that supply line rubbish cannot get through to the signal channels – perhaps by the use of separate supply lines.

The third, and sonically most important, use of a capacitor is as the d.c. blocking component in an amplifier negative feedback network, of the kind I have shown in Fig. 8. Here, in theory, the gain, (M), of the amplifier block, at frequencies where the a.c. impedance of the capacitor is low in relation to Rb, is given by $M = Ra + Rb/Rb$. But, we have already seen that all capacitors have some element of parasitic resistance in series with the capacitance, and this hidden and undeclared resistance, which I'll call Rx, modifies the gain so that it is now

$$M = \frac{Ra + (Rb + Rx)}{(Rb + Rx)},$$

which is different.

Unfortunately, "Rx" is a long way from being an ideal resistor, and its value is likely to be voltage, temperature, polarity and frequency dependent, as well as being influenced even by the shape of the a.c. waveform applied to it.

Since the effective value of Rx is likely to be a significant fraction of the value of Rb, and will, in consequence, have an effect on the gain of the system, the remarkable thing is that the non-linearity of the series loss resistance of, for example, an electrolytic capacitor, used in this position, has so small an effect on the total harmonic distortion, (THD), of the amplifier, measured at, say, 1kHz.

If, however, one measures the intermodulation distortion, (IMD), effects produced when the amplifier is driven by several simultaneous input signals, using a spectrum analyser to track down the spurious signals which have been generated, then the differences between one type of d.c. blocking capacitor and another used in the negative feedback loop, due to the various real-life imperfections in its operation, are more easily seen. Changing the type of capacitor used in this position does indeed affect sound quality – which is what the IMD measurements will point out, especially if one of the input signals used in this test is of square-wave type.

WHAT ABOUT TRANSISTORS

Our old friends, the "bipolar" junction transistors, (*pnp* or *npn*), have many virtues. They are very reliable, when they are used within their ratings, they can have a very low intrinsic noise level, and they are cheap. Unfortunately, from the point of view of audio, they are very non-linear in their input-output transfer characteristics, and the large power ones can be pretty sluggish in their high frequency response, which leads to large and inconvenient phase shifts in the signal passing through them.

Two particular audio problems with (junction) power transistors are due to the presence of "minority carriers" and to "hole storage" effects – problems which are most noticeable at high current levels through the devices, especially if they are turned as hard on as they can go. When they are driven into this state, they are sluggish about turning off again, as I have shown in Fig. 9, which

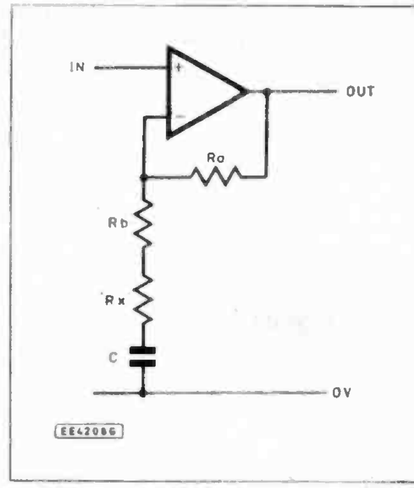


Fig. 8. Real-life feedback system including capacitor loss and series resistor.

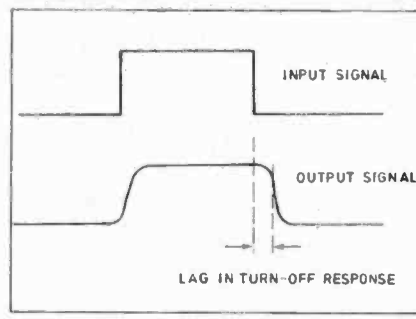
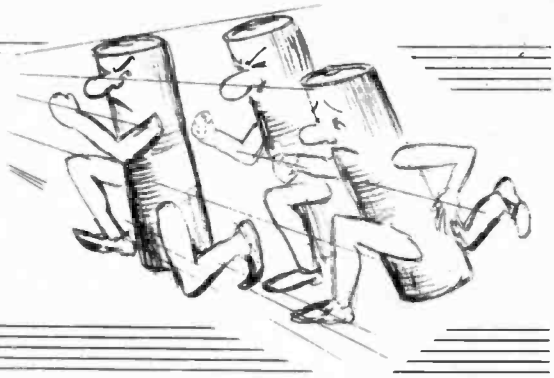


Fig. 9. Transient lag characteristics in junction power transistors.

spoils their response to transients. This problem muddies the high signal level sound quality. Choosing a fairly low value for the base-emitter circuit resistance helps reduce this defect, and can give a cleaner treble.

Power MOSFETs do not suffer from this snag, and do, in my opinion, give a much cleaner and more "open" quality, especially in the treble. However, they also have other advantages which make them preferable in audio amplifiers, and I will look at the influence of circuit design, and the choice of transistor types, on audio quality in the next part of this article.

Constructional Project



CHARGE-15

IVAN PATRICK GORE

Quarter-hour charging for AA NiCad batteries.

CHARGE-15 is a mains-operated unit designed to charge a set of the popular "AA" type (HP7 size) nickel-cadmium cells in about 15 minutes – hence the name. This time compares with 15 hours for commercial *standard charging* units and between two and five hours for the *fast charge* variety. It will thus be found useful whenever batteries are likely to let you down suddenly or where it is essential to have ready access to a fully-charged set.

Charge-15 is designed to charge sets of either *two* or *four* AA cells, these being the most usual arrangements. It should *only* be used where cells are of the *same make* and have a *similar history* and should not be used where other numbers of cells are involved. *Note that on no account may this unit be used in an attempt to charge standard (non-rechargeable) batteries. Doing this is likely to cause them to overheat and rupture.*

Constructing this circuit involves making mains connections. *Any reader who is not certain of being able to build it safely **MUST** therefore seek professional advice.*

An accurate ammeter (or multimeter) capable of reading up to 2A d.c. must be made available at the setting-up stage. Many analogue multimeters do not have a scale which reads high enough. However, digital instruments usually do and readers who do not own a suitable meter will need to borrow one.

ULTRA RAPID

Ultra-fast charging is not thought to be particularly good for batteries and it is possible that they may suffer from some shortening of life. However, in tests on the prototype unit, cells were repeatedly charged and discharged over 50 cycles and were found to be still in perfectly good condition at the end with no significant loss of capacity.

Since a nickel-cadmium cell costs little more than the throw-away alkaline variety these days (about £1 compared with 70p) any shortening of life is thought to be of little consequence even taking into account the much lower energy content (one fifth approximately) of rechargeable cells compared with alkaline ones.

AMP-HOUR CAPACITY

The *capacity* of a cell is related to the amount of energy stored in it. This is expressed in Ah *(amp hours)* – that is, the current it supplies expressed in amps multiplied by the number of hours during which it can maintain this. Where small batteries are used, the capacity is often expressed in mAh – i.e. the number of milliamps multiplied by the time in hours. Since 1A = 1000mA, 500mAh is the same as 0·5Ah.

There are two types of AA nickel-cadmium cell in current use both having the same body size – standard (500mAh) and the higher capacity (600mAh to 700mAh) variety. Either type may be used with this unit but a *mixture* of different capacities should *not* be charged.

The capacity figure must be regarded as approximate and will depend on the load, it reduces as the current drawn increases. Thus, if the capacity of a given cell is 100mAh then it could supply 10mA for 10 hours or, say, 20mA for 5 hours. However, it is doubtful if it could maintain 500mA for 12 minutes.

STANDARD CHARGE

Most units sold "over-the-counter" charge AA nickel-cadmium cells at a current of 50mA approximately. With a 500mAh cell, the theoretical charge time is therefore 10 hours. However, the charging process is not 100 per cent efficient and, in practice, more energy needs to be supplied than will be ultimately obtained – the excess energy being converted into heat. To charge a standard capacity cell, some 750mAh will need to be supplied giving a charging time of 15 hours.

With this type of charger, no harm will result if the cell is left connected so that current flows continuously (standby operation). Conventional fast chargers operate at a higher current, 150mA approximately, to provide a full charge in five hours. These chargers often drop back to the "trickle" (standby) rate after this time.

It is possible to charge nickel-cadmium batteries in a much shorter time by using an even higher charging current. However, to avoid damage to them it is essential to observe certain precautions – particularly to avoid overcharging and overheating.

To prevent overcharging, the current must be carefully controlled and the charging time monitored. In practice it is found that a full charge cannot be delivered in this way and, to be safe, the cells will be charged to rather less.

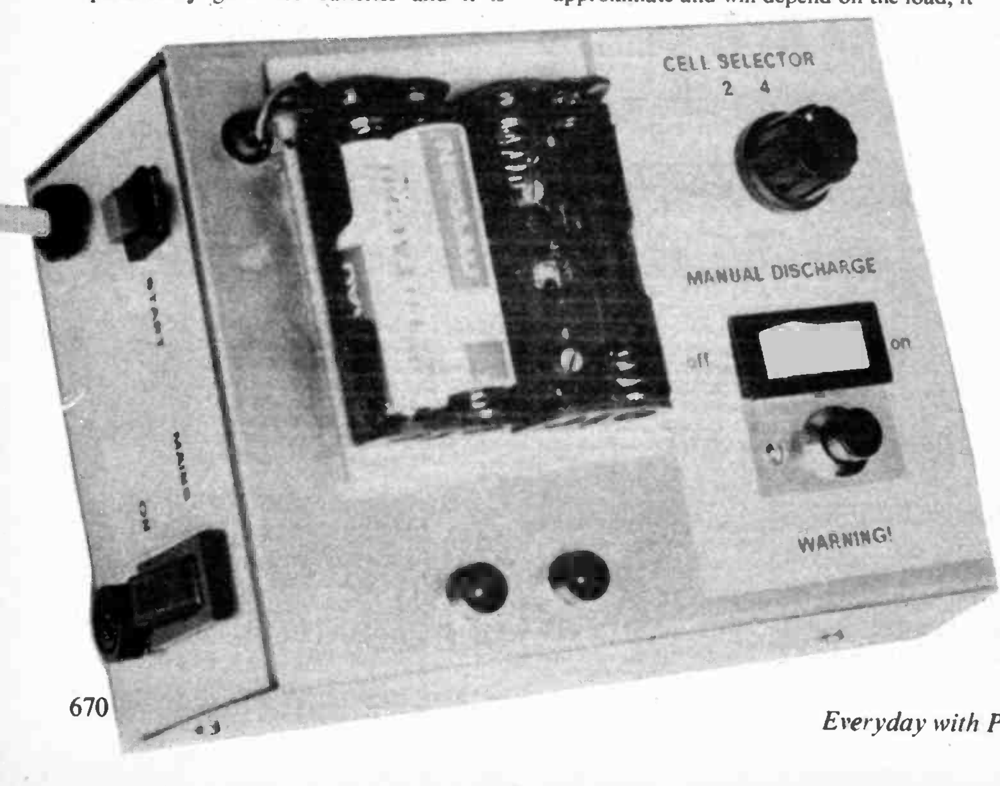
It is said to be possible to charge an AA nickel-cadmium cell at a rate of up to *ten times* its rated capacity (10C) – that is, up to 5A in the case of a 500mA cell. This is thought to be carrying fast charging too far and unnecessary for normal purposes.

Although it could mean spectacularly short charging times, overheating problems would tend to occur. Also, using such high currents would add to constructional cost due to the increased price of the uprated mains transformer and other components.

On balance, it was considered that a charging time of 15 minutes (plus an initial discharge time) based on 500mAh cells was short enough for most practical purposes. This corresponds to using a current of 2A which may be obtained using relatively inexpensive components.

In conventional *slow* charging, the excess heat produced in the cells is dissipated over a long period of time and they remain cool. In *fast* charging, they will become warm. To avoid overheating, it is necessary to monitor the temperature and reduce the current should it rise above a preset maximum of around 45°C.

In Charge-15 battery overheating should



not occur unless cells are inserted the wrong way round, one of them is faulty or possibly due to a high ambient temperature. If overheating does take place and the current so reduced, this will result in a smaller charge being delivered but, in practice, this is of little consequence.

Under severe conditions of abuse nickel-cadmium cells become very hot and build up a pressure inside the case. To prevent possible explosion, a safety valve is fitted. This is designed to open at some 200lb/in^2 and close again when the pressure falls to 175lb/in^2. Such venting is thought to be provided very much as a last resort.

AUTO-DISCHARGE

To ensure that the charge is delivered accurately, the cells must first be almost completely discharged. This means that the unit is unsuitable for "topping up" the charge in cells. Such topping-up by whatever type of charger is not a good idea anyway – nickel-cadmium cells respond much better to complete charge/discharge cycles and this avoids any *memory effect* (a little information about the *memory effect* is given at the end).

Battery discharge will usually be indicated when the equipment being powered by it fails to work. However, it is still necessary to ensure that the discharging process is complete before charging begins.

This is done automatically by Charge-15 which starts the cycle by applying a heavy load for one to two minutes. Although this ensures that the cells are sufficiently "flat", they are not totally (deep) discharged and the terminal voltage will remain above one volt or thereabouts.

Allowing the voltage to fall further than this can sometimes cause problems. There is a check provided in the form of a filament lamp which lights if a cell has been inserted which is significantly charged already.

USING THE CIRCUIT

In use, the charger is set for either two or four cell operation by means of a rotary switch. The cells are then inserted into the holders on the top panel. The unit is plugged into the mains, switched on and the *start* button pressed.

If the red filament *warning* light comes on, this indicates that the batteries are partially charged already. If it goes off within a few seconds, no action need be taken.

However, if it remains on for any length of time, the cells may be returned to the equipment from which they were removed to discharge them completely (which is the preferred method) or the charger itself used for this purpose. To do this, a manual discharge switch is operated and the cells left until the light goes off. The switch is then reset and a normal charging cycle begun.

CIRCUIT DESCRIPTION

The complefe circuit circuit for Charge-15 is shown in Fig. 1. The low-voltage supply needed to operate the electronic section and to provide battery charging is obtained from the conventional arrangement of mains transformer T1, full-wave rectifier diodes D1 and D2 and smoothing capacitor, C1. Fuse, FS1, provides protection in the event of accidental overload or short-circuit.

After switching on at mains switch, S1, a supply is established by pressing push-to-make Start switch, S2. This allows current to flow through the transformer primary winding.

The low-voltage supply so obtained initiates the twin precision timers based on integrated circuits IC1 and IC2 with current flowing through resistors R3 and R6 respectively. Current also flows to regulator IC3 whose purpose will be described later.

The timers IC1 and IC2 are connected in *self-triggering* mode. Thus, as the supply voltage rises, both timers are actuated and their respective outputs (pin 3) go high for a time determined by external components then revert to low.

With IC1 output high, base current enters transistor TR1 via current-limiting resistor, R4, and collector current flows through the relay coil RLA. The normally-open (n.o.) contacts, RLA1, of the relay then "make" and by-pass switch S2. Thus, the mains supply is maintained when the finger is removed from the switch. All this happens almost instantaneously so S2 need only be pressed for an instant.

With a supply established, the green Operate l.e.d. D3, lights via current-limiting resistor, R1. At the end of IC1 time period, relay RLA switches off and the "make" contacts part to interrupt the mains supply. The cycle ends and the Operate l.e.d. goes off.

The time period of IC1 is set by the values of resistor, R2 and capacitor, C3. Adjustment to the timing is provided over a wide range by preset VR1 connected as a variable resistor between IC1 pins 11 and 12.

While IC1 is timing over a nominal 15-minute period, IC2 performs a similar function but over a shorter one – about one to two minutes. Thus IC2 will switch off while IC1 is still in the process of timing. IC2 time period is set by the value of resistor R5 in conjunction with capacitor, C5 with preset potentiometer VR2 forming the adjustment in a similar manner to IC1.

With IC2 output *high*, transistor TR2 operates, with base current flowing via resistor R8, and drives the coil of relay RLB. Contacts, RLB1, then change over to the normally-open ("make") position. This provides the initial discharge function to be described presently. The l.e.d., D5, operates in conjunction with current-limiting resistor R7 to show that this section is operating.

BINARY COUNTER

Before proceeding, some readers may wish to know a little about how timers IC1 and IC2 operate – if not, this section may be omitted. Both timers work in identical fashion so it is only necessary to explain the action of one of them.

Consider the timer based on IC1 and associated components. This self-triggers as the supply voltage rises and capacitor C3 charges through resistor R2 so that the voltage at pin 13 rises.

At a certain value, an on-chip binary counter registers a count of *one* and the capacitor is discharged to begin a further cycle. This repeats until 4095 such charge/discharge cycles have been counted

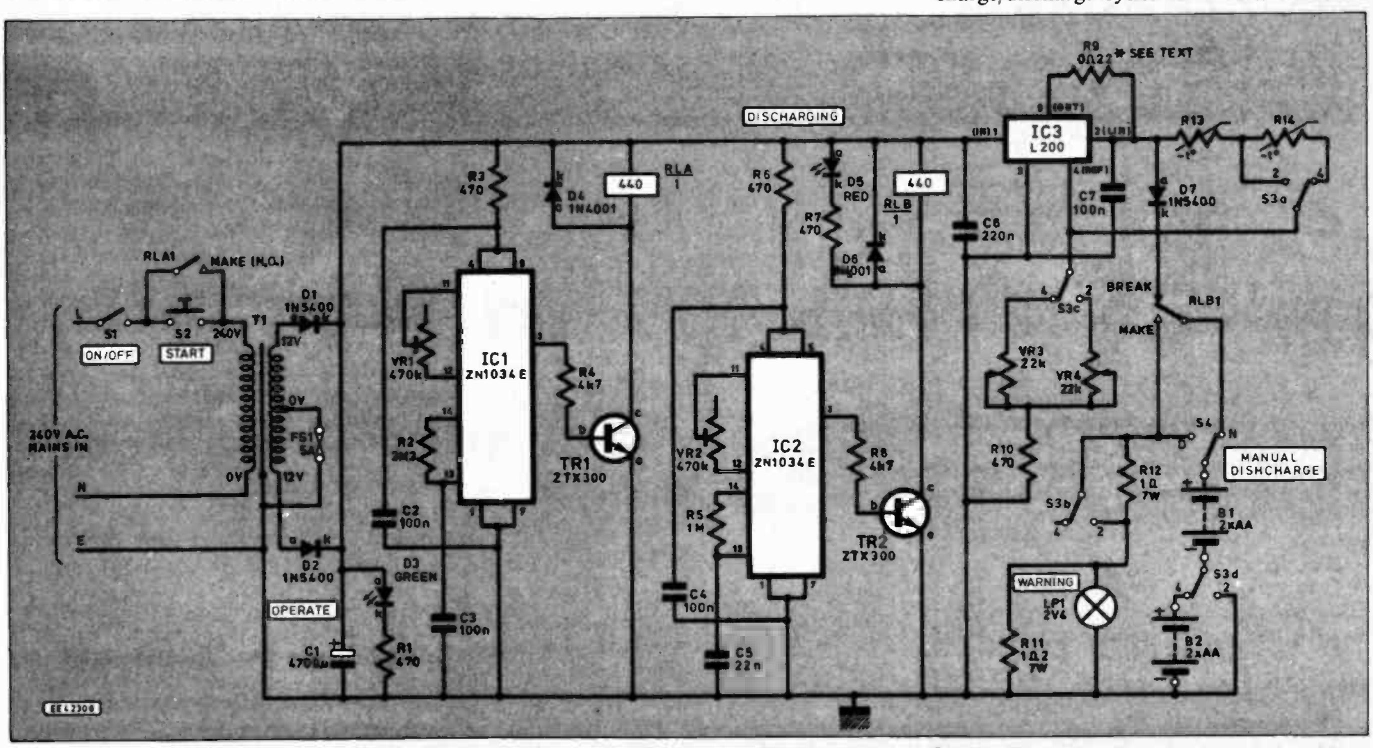


Fig. 1. Complete circuit diagram for the Charge-15 fifteen minute NiCad battery charger.

whereupon the output goes *low* – that is, it switches off.

Resistor R3 acts in conjunction with an internal on-chip 5V regulator to provide a precise 5V supply for the i.c. Capacitor C2 is necessary to provide internal stability.

Diodes D4 and D6 by-pass the reverse high-voltage pulse which occurs when the magnetic field in the respective relay core suddenly collapses on switching off. This could otherwise damage semiconductor components in the circuit.

POLES APART

Switch S3 is a four-pole three-way rotary type but in this application, only *two* positions are used. Each position corresponds to a number of cells – either *two* or *four* and in Fig. 1, these are labelled "2" and "4" respectively. Note that the switch is shown in the position "4". The four poles labelled a, b, c and d are used for the various purposes to be described presently.

Suppose a supply is established with both relays, RLA and RLB, energized. Suppose also that two cells have been selected by means of switch S3 and the Manual Discharge switch S4 is set to Normal (N).

Current flows from the positive terminal of the 2-cell battery, B1, via S4(N) and RLB "make" contacts through S3b pole contacts. From here it flows through resistor, R11 and filament lamp LP1 connected in parallel with it, with current returning to B1 negative terminal via S3d pole.

The low value of resistor R11 imposes a high load, 2A approximately, and the lamp itself imposes a further 0·5A so any remaining charge in the cells is soon dissipated. This is the "self-discharge mode".

If four cells have been selected there arises a similar situation but this time both pairs of 2-cell batteries appear in series through S3d pole. Discharging now takes place through both resistors R12 and R11 which appear in series, and through lamp LP1.

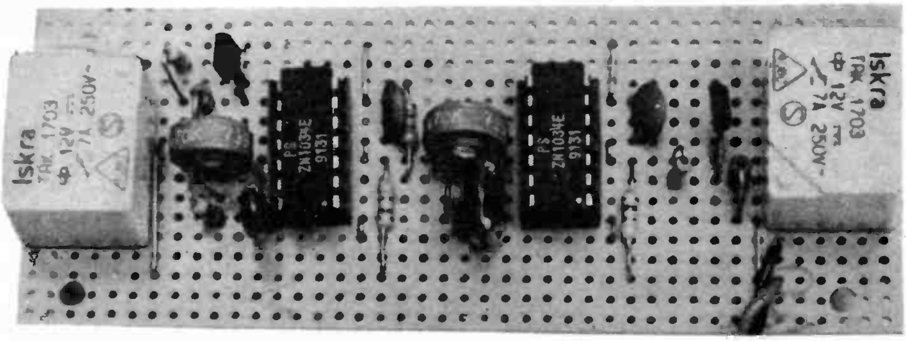
The lamp has a voltage rating of 2·4V which is correct for two cells but when four cells are selected (4·8V) resistor R12 limits the operating current to the correct value. A discharged cell will have insufficient voltage across its terminals to light the filament lamp. However, if the voltage is high enough due to the battery still retaining some charge, the lamp will operate providing the warning mentioned previously.

When IC2 time period is complete but IC1 still has some time to run, RLB/1 contacts change over to the normally closed ("break") position. The discharging process ends and current is now directed from regulator IC3 output, via diode D7 and S4(N) contacts to the batteries being charged – either two or four cells according to the position of S3d. Charging current will then flow until IC1 times out and the whole circuit switches off.

Should the cells require a substantial amount of discharging before a normal cycle is begun, switch S4 provides a *manual discharge* function. Thus, by switching it to the Discharge (D) position, the cells may be discharged for an indefinite time independent of the action of the rest of the circuit. It is therefore not necessary to have the mains switched on for this.

Regulator IC3 is a sophisticated device with on-chip regulation of both *current* and *voltage*. It also contains circuitry to shut the device down in the event of overload or overheating.

Resistor R9 sets the current delivered by the output (pin 5) to a value of 2A. In practice, due to component tolerances and



Component layout on the completed stripboard.

other details, this must be regarded as approximate and it may be necessary to modify the value of this resistor so that the correct current is provided.

HOT STUFF

The possibility of cell overheating is prevented by the arrangement of thermistors R13 and R14. These are placed close to the cells being charged. Thermistor R13 is responsible for the pair B1 while R14 is responsible for the other set, B2.

With S3 set for *two* cells, S3a connects R13 alone. When four cells are selected, both R13 and R14 appear in series. Similarly, when two cells are selected, S3c calls preset potentiometer VR4 into play and with four cells, VR3 is connected instead.

Whichever preset is selected, resistor R10 appears in series with it. This is a precaution against setting either preset to zero by accident. This could cause excessive current flow in the thermistors if they were already hot.

The arrangement of thermistors and presets described above sets a control voltage on IC3 pin 4 and this, in turn, determines the output voltage developed at the cathode (k) end of diode D7. With correct adjustment to presets VR3 and VR4 and with the thermistors cool enough, this voltage will normally exceed the nominal battery voltage and thus will be sufficient to charge the cells.

As the temperature of a cell or cells rises, the resistance of the appropriate thermistor(s) falls and this results in a lowering of the control voltage and a consequent turning down of the charging current. If the output voltage falls below the battery voltage, charging stops altogether.

The presets will be adjusted at the end of construction to provide this roll-off characteristic when the temperature rises higher than normal. Diode D7 prevents current flowing back from the cells being charged through IC3 and associated components.

HOUSING

CHARGE-15 MUST BE HOUSED IN AN EARTHED ALUMINIUM BOX. This is mainly because various components become hot in operation and the metalwork is used as a heatsink.

Note that S3 must be a rotary switch of the "*break-before-make*" type and having a contact rating of 2A minimum. The switch is not called upon to *switch* the current – only to *carry* it so the normally-quoted contact rating of around 400mA will, in practice, be found adequate (see components list).

Timing capacitors C3 and C5 must be of a high quality – see components list. Ceramic capacitors are unsatisfactory here as their value changes significantly as they become warm and would affect the timings as the temperature inside the case increased.

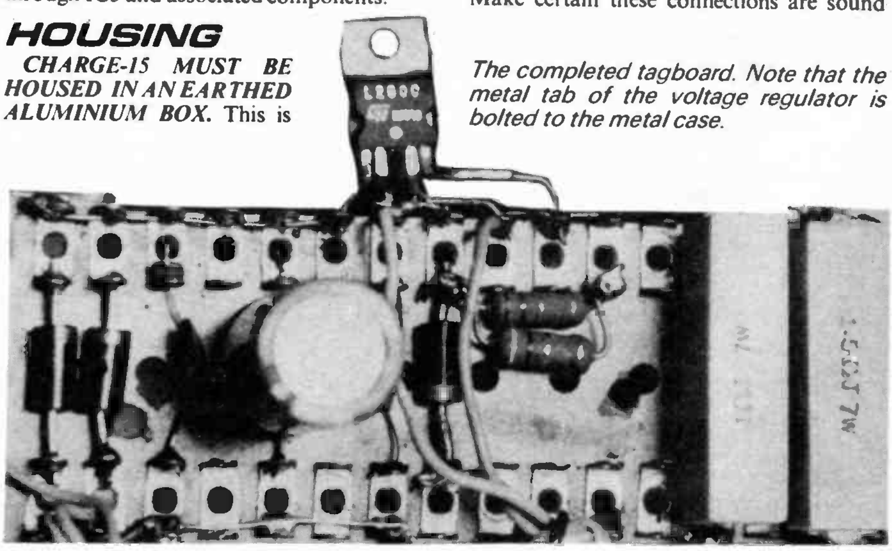
CIRCUIT PANELS

Construction of Charge-15 is based on a main circuit panel made from a piece of 0.1 inch matrix stripboard, size 42 holes x 16 strips. Fig. 2 shows full topside component layout and details of breaks needed in the underside copper tracks. In addition to this, certain components are mounted on a subsidiary tagboard panel – details for this are shown in Fig. 3.

Begin by constructing the main circuit panel. Cut the material to size, drill the four mounting holes and make all track breaks in the positions indicated. Solder the inter-strip link wires in position, noting that the link connecting IC1 pins 1 and 7 is impossible to add after the i.c. socket has been soldered into position.

Follow this with the soldered on-board components then make a careful check for errors. Complete construction of the panel by soldering 15cm pieces of stranded connecting wire to matrix positions *C6* and *E6* as indicted.

Solder 20cm pieces *mains wire of 3A rating minimum* direct to the "make" contacts of relay RLA – i.e. *not via the copper strips*. Make certain these connections are sound



The completed tagboard. Note that the metal tab of the voltage regulator is bolted to the metal case.

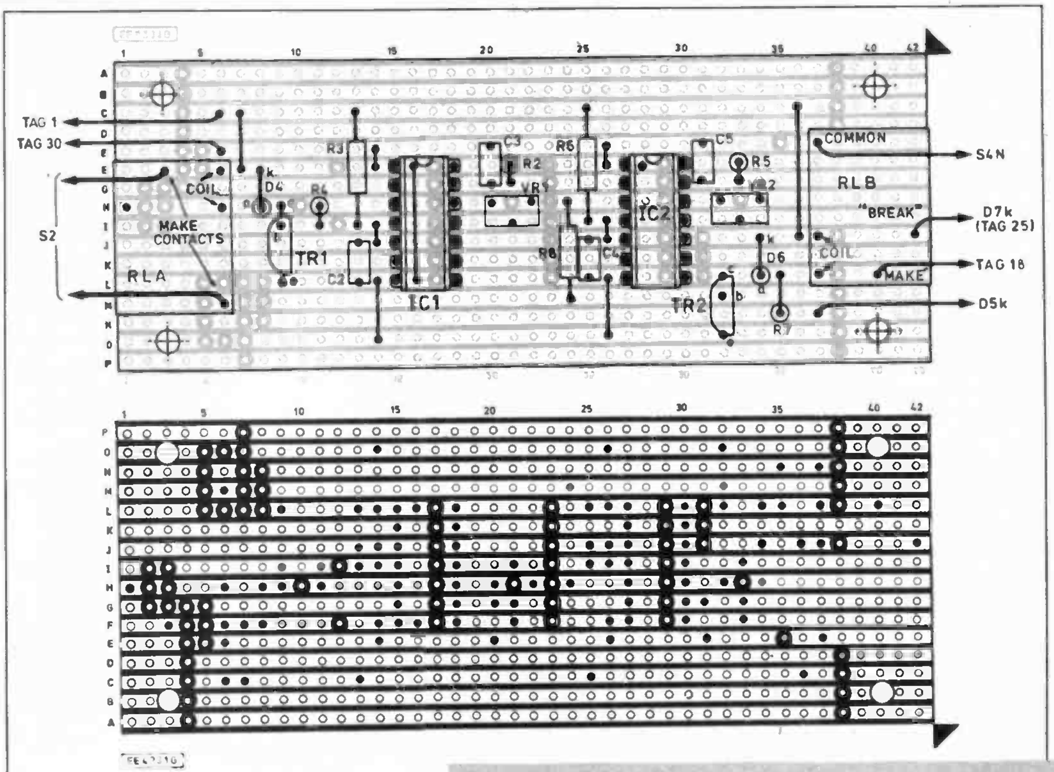
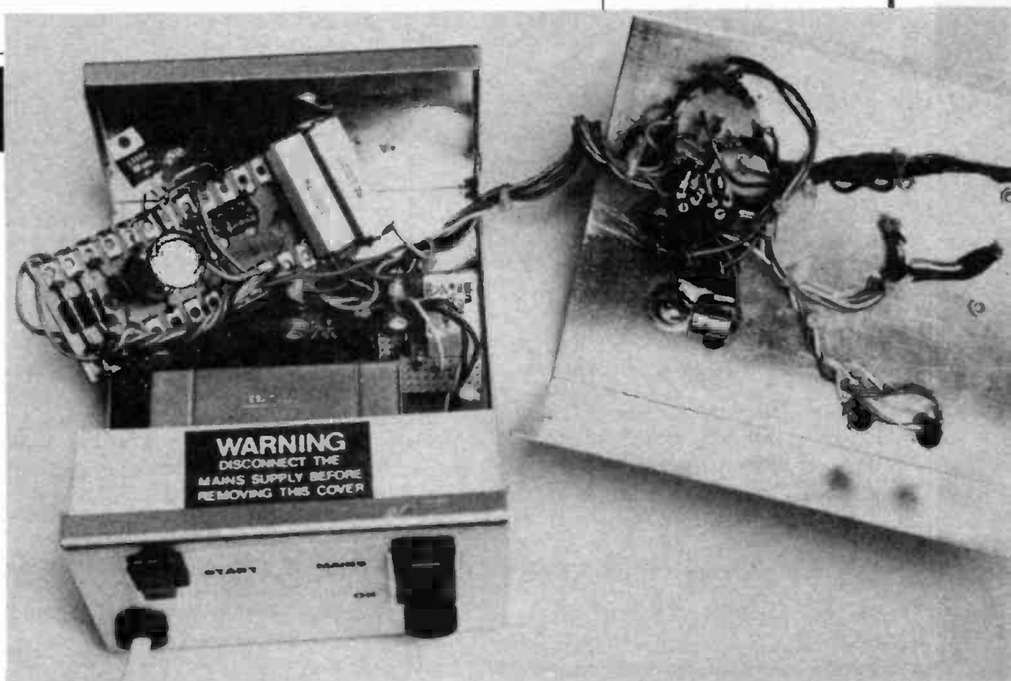


Fig. 2. (left). Striboard component layout and details of breaks required in the underside copper tracks.

The leads from the make contacts of RLA are soldered directly on to the relay connecting tags and must be 3A rating minimum.

See SHOP TALK Page

(below) The completed unit showing wiring to cell selector switch and wires passing through the l.e.d. to the cell thermistors. The tag board is bolted to the side panel.



COMPONENTS

Resistors:

R1, R3, R6, R7, R10	470 (5 off)
R2	3M3
R4, R8	4k7 (2 off)
R5	1M
R9	0Ω22 (and possibly 0Ω47 and 1Ω) 1W (see text)
R11	1Ω2 7W
R12	1 7W
R13, R14	Bead thermistors resistance at 25°C 15k approx. (2 off)

All resistors 0·25W 5% unless shown otherwise.

Potentiometers

VR1, VR2	470k min. carbon preset, vert. (2 off)
VR3, VR4	22k min. carbon preset, vert. (2 off)

Capacitors:

C1	4700µ radial elect. 16V
C2, C4, C7	100n ceramic (3 off)
C3	100n polyester or Mylar film
C5	22n polyester or Mylar film
C6	220n ceramic

Semiconductors

D1, D2, D7	1N5400 50V 3A rect. diodes (3 off)
D3	5mm green l.e.d.
D4, D6	1N4001 50V 1A rect. diodes (2 off)
D5	5mm red l.e.d.
TR1, TR2	ZTX300 *npn* silicon (2 off)
IC1, IC2	ZN1034E precision timer (2 off)
IC3	L200 voltage/current regulator 2A

Miscellaneous

RLA, RLB	Miniature relay 12V, 400 ohm coil, relay with single-pole changeover contacts rated at 240V a.c. 5A (2 off)
T1	Mains transformer with 12V – 0V – 12V secondary or twin 12V secondaries rated at 25VA
S1	SPST 240V mains-rated rocker or toggle switch. 1A contacts minimum.
S2	Miniature push-to-make switch with 240V mains-rated contacts rated at 1A minimum.
S3	4-pole 3-way rotary switch – break-before-make action. Contacts rated at 2A *carrying capacity* minimum.
S4	Toggle or rocker switch with make contacts rated at 2A d.c. minimum.
FS1	20mm panel fuseholder with 5A anti-surge fuse
B1, B2	Double AA-type battery holders having PP3-type connectors (2 off)
LP1	2·4V 0.5A bulb with holder and lens to suit (see text)

Stripboard 0·1in. matrix, size 16 strips x 42 holes; aluminium box, size 152mm x 114mm x 76mm; tagboard panel – two rows of 16 tags needed; PP3 battery connectors (2 off); 14 pin d.i.l. socket (2 off); self-adhesive plastic feet (4 off); spring-clip for LP1, if required; solder tags (3 off); stranded connecting wire; 3A 3-core mains wire; small fixings; solder, etc.

Approx cost guidance only **£29**

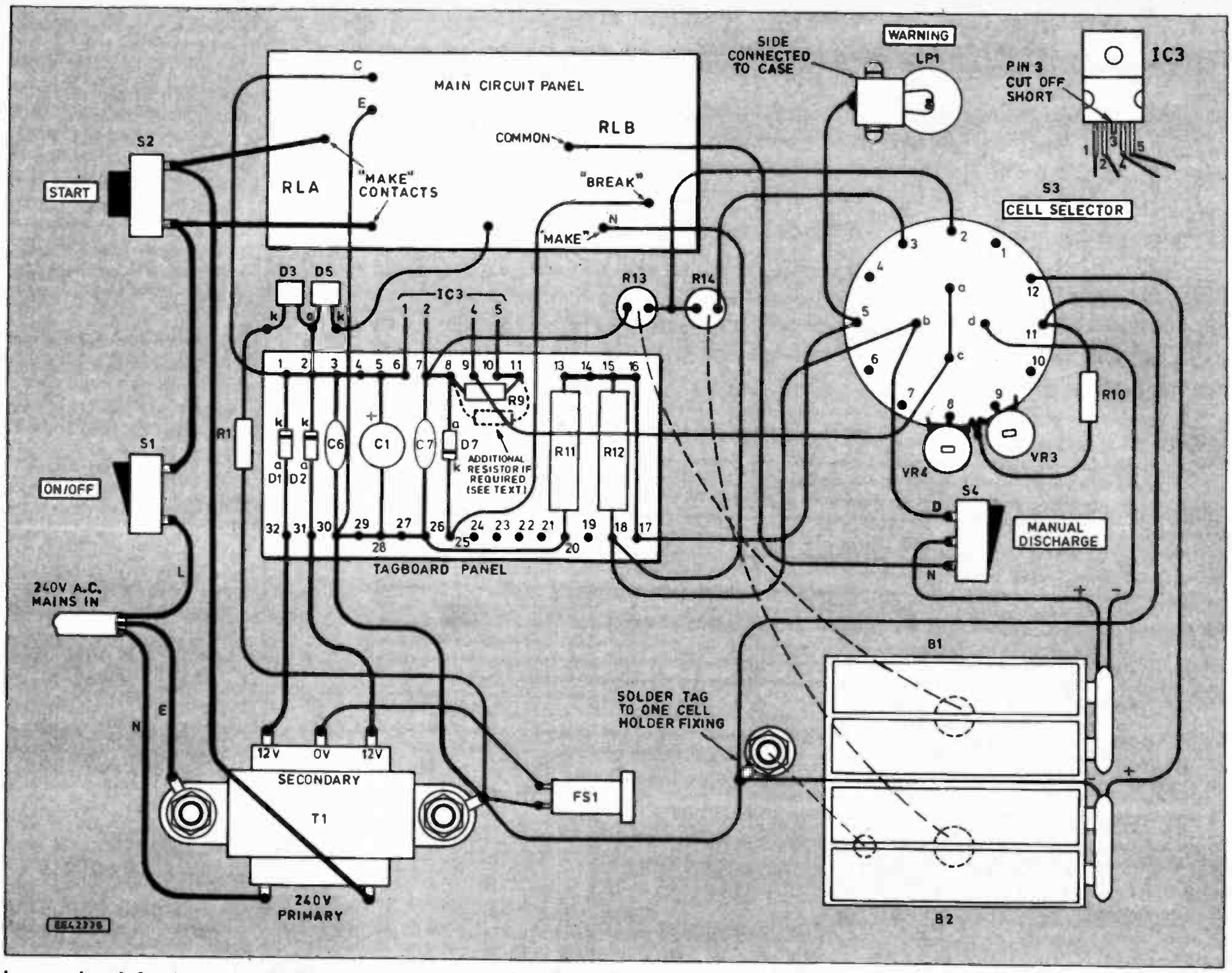


Fig. 3. Interwiring between the two boards and all off-board components. Connections to relay RLA "make" contacts are made by soldering 3A (minimum) mains wire direct to the relay tags.

and cannot break free in service. At the same time, check that the copper tracks adjacent to these connections are *completely* broken – this is essential for safety reasons. Solder 20cm pieces of stranded connecting wire to the changeover contacts of relay, RLB.

TAGBOARD

Refer to Fig. 3 and construct the tagboard panel. Cut the material to size (two rows of 16 tags) and make the inter-tag links. Mount the on-board components as indicated taking care over the polarity of electrolytic capacitor, C1. Note that resistors, R11 and R12 become hot in operation so they must be mounted a few millimetres clear of the panel to allow ventilation.

Cut off IC3 pin 3 close to the body. This is possible because the metal tab when bolted to the metalwork automatically makes this connection. With care, bend the remaining pins to the form indicated in photographs.

Pins 4 and 5 of IC3 should be extended using single-core wire to reach the positions indicated. Leave space for the additional resistor which may have to be connected in parallel with R9 to obtain the correct output current (shown in dotted lines in Fig. 3).

CASE FOR VENTILATION

Hold the two sections of the case together then raise the top part so that there is a gap of 4mm at each side. Mark through the existing holes in the top section on to the flanges of the lower one and drill new holes to correspond with these.

Check that the case re-assembles correctly with the self-tapping screws used in the new holes. These gaps are necessary to allow a flow of air to circulate through the case for ventilation purposes.

Drill holes in the base of the case for mains transformer T1 and for main circuit panel mounting. Drill holes in the end panel for tagboard and IC3 mounting. Make holes for all switches, l.e.d. indicators and for fuseholder FS1. Drill a hole to accommodate the strain relief grommet to be used on the mains input lead.

Drill holes and mount the cell holders – note the solder tag on one of the fixings. Include a piece of thick cardboard beneath the holders – this is necessary to provide heat insulation and prevent the cells from becoming too warm in operation. This could cause the operating current to turn down prematurely due to warming the thermistors.

Drill holes through the centre of each cell holder and through the metal case (those used in the prototype unit already had convenient holes). These will be used to accommodate the bead thermistors later.

Drill a hole for lamp LP1 holder. This component may cause problems, there do not appear to be neat panel lamp holders for this type of bulb. The smaller LES lamps for which holders are supplied are not available in the correct voltage and current rating.

The method used in the prototype was to use a panel lamp holder designed for an LES bulb and to discard all but the lens and bezel. The lamp itself was mounted using a small spring clip – this holds it securely beneath the lens and also connects the side contact to the metal case as required. The end connection to the bulb is made by careful soldering. A cardboard shield around the lamp is cosmetic in preventing light emerging from the ventilation slots in the case.

Mount the mains transformer T1, including solder tags on both fixings – these will be used for "Earthing" purposes later. Mount the tagboard panel temporarily on the end panel using a thick piece of cardboard beneath the board to provide insulation.

Follow this by mounting the main circuit panel using short stand-off insulators on the bolt shanks. *Great care must be taken to ensure that all connections on the copper strip side remain at least 4mm clear of the metalwork.* This is essential for safety reasons. As with the tagboard panel, use a thick piece of cardboard beneath as an additional precaution.

TWO POSITIONS

Before mounting rotary switch S3, it is necessary to adjust it so that only two positions can be selected. This is a little-known art and many people do not know how to do it or, indeed, that it is possible.

Begin by removing the nut and washer from the spindle. Underneath will be found a tab washer which may be removed to reveal a ring of holes in the plastic body where the tab can rest.

In its original position, the moving contact can take up one of *three* positions. However, by replacing the tab in a different hole, the correct configuration will be found where it can only move to *two* positions.

There are numbers 1 to 12 inscribed on the body next to the tags. The "impossible" positions should be 1, 4, 7 and 10. This point may be checked using a multimeter with a "buzz-test" or simply a battery and bulb.

Extend the end leads of the thermistors (R13, R14) using narrow-bore heat shrinkable sleeving on the wires. Not only will this provide insulation but will also give protection against possible cutting of them by the metal box when they are in position.

Mount the thermistors in the holes drilled in the cell holders using quick-setting epoxy resin adhesive to secure them. These should rest in such a position that they sense the air temperature around the cells without actually touching them. This is because thermistors are fragile and easily damaged.

INTERWIRING

Refer to Fig. 3, mount remaining components and complete the internal wiring – it will be necessary to remove the tagboard panel for this. The use of stranded wire of different colours – for example, "rainbow" ribbon cable – will help in avoiding errors. However, all wiring shown in bold type (thick leads) must be *mains type of 3A rating minimum.*

TABLE 1:
Tag numbering for switch S3

Pole	2 Cells	4 Cells
	Tag number	
a	2	3
b	5	6
c	8	9
d	11	12

Table 1 shows a mapping of the function of switch S3 poles a to d against the tags as numbered on the plastic body. Note resistor R1 soldered in-line with l.e.d. D3. Note also resistor R10 at S3 position and the manner in which presets VR3/VR4 are soldered directly to the switch tags.

Tighten all fixings. Re-attach the tagboard panel. Finally, tidy up the wires by using small cable ties as shown in the photograph.

Cut off a suitable piece of 3-core *mains-type* wire of 3A rating to use as the inlet lead. Install it as shown in Fig. 3, making certain that the connections are secure and cannot dislodge in service. Fit the strain relief grommet and attach the lead in position.

Make a thick cardboard shield for the mains connections at T1 and at S1 and S2 position. Secure this in position – see photograph. *Make certain that this shield will prevent touching of any mains connections either with the fingers or with a metal tool.*

Leave presets VR1 and VR2 adjusted to approximately mid-track position. Adjust VR3 fully *clockwise* and VR4 fully *anti-clockwise*. Fit plastic feet to the underside of the case.

Attach the mains plug and fit it with a 2A fuse. Readers using a non-UK pattern plug should fit a separate 2A mains fuse inside the case. Insert a 5A anti-surge fuse in the panel fuseholder.

SETTING-UP AND TESTING

Important note: ***Due to mains connections existing inside the case, all adjustments to presets VR1 to VR4 – and any other adjustments – MUST be made with due care. Check that it is*** absolutely impossible ***to touch any mains connections at the transformer primary, switches S1, S2 or elsewhere.***

Set the "test" ammeter to a range which covers 2A d.c. If the test prods can be fitted with small crocodile clips, the procedure will be made much easier. Insert two discharged cells in the appropriate cell holder observing the polarity. Swivel the battery connector so that only the negative connection is made. Switch on the mains and press S2 for an instant. Both l.e.d.'s should light.

It is necessary to wait until the red Discharging one (D5) goes off before proceeding. When this happens, connect the ammeter between the battery holder positive connection and the free end of the connector as shown in Fig. 4.

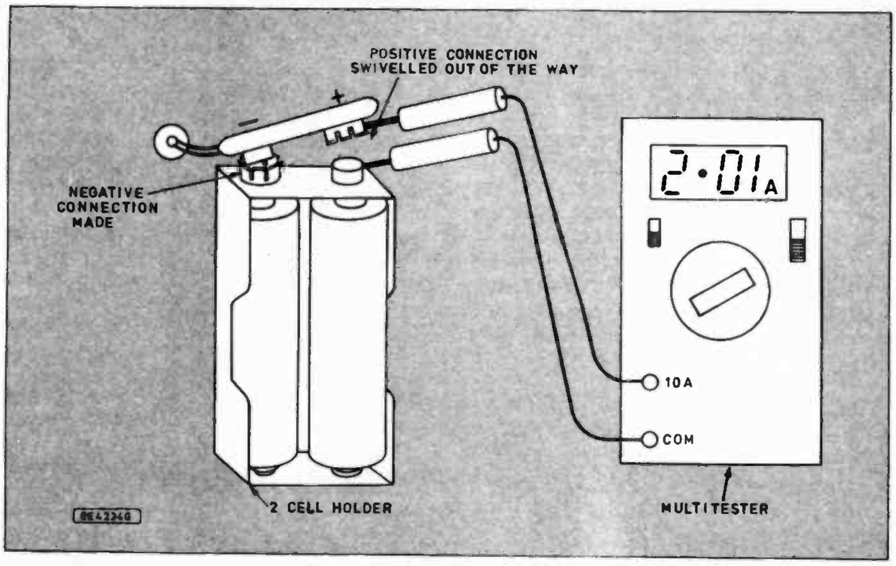


Fig. 4. Using test meter, set to amperes range, to check charging current.

Observe the meter reading – the current should be 2A approximately. If it is not near this value, resistor R9 will need to be adjusted – raising its value will reduce the current and vice-versa. Note, however, that it is acceptable for the current to exceed 2A (up to, say, 2·2A) providing it falls to 2A or below within half a minute or so.

If R9 needs to be reduced in value, first try simply short-circuiting it. If this results in a current exceeding 2·1A, remove the short-circuit and connect an additional resistor in parallel with it – see Fig. 3.

Try a value of 0·7 ohm in the first instance or one ohm if the current then exceeds 2A. It is unlikely that R9 will need to be *increased* – if it does, try a 0·27 ohm resistor in place of the existing one in the first instance.

SETTING TIMES

The timings for initial discharge and total cycle (that is, initial discharge *plus* charging time) are adjusted by means of presets VR2 and VR1 respectively. Note that no cells need be inserted for this to be done. It will probably be necessary to make a short screwdriver to enable the presets to be adjusted with the circuit panel in position – a short piece of plastic rod with the end filed to shape will serve.

The initial "discharge" time should be set first. Adjust preset VR2 clockwise (as viewed from mains transformer T1 position) to provide a period of one to two minutes or as required. Next, adjust VR1 to provide the correct "charging" period (that is, the time elapsing after the red Discharging l.e.d. goes off. Again, clockwise rotation of VR1 (as viewed from T1 position) increases the time period.

For charging 500mAh cells at 2A, a timing of 15 minutes ***maximum*** is advised. If the charging current is a little less than 2A and there is no wish to increase it, the timing may be increased in proportion. Similarly, if 600mAh cells are being charged, a timing of 18 minutes may be used. Note that the capacity is marked on the cell body.

Attention may now be given to adjusting presets VR3 and VR4. Insert a pair of discharged cells known to be in good condition. Press S2 to initiate the cycle. Near the end of the charging time, the cells may feel warm and VR4 should be adjusted *clockwise* until the charging current *just* shows signs of falling then slightly anti-clockwise again.

Repeat the procedure with four cells on charge and with VR3 adjusted first *anti-clockwise* then clockwise again for the same effect. If the cells remain too cool to do this, the temperature may be increased *slightly* by careful use of a hair dryer.

Attach the lid making sure that all internal wiring remains clear of resistors, R11 and R12 since these can become hot in operation and could damage any insulation which comes into contact with them. *With the unit unplugged from the mains*, check that a metal object pushed into a ventilation slot cannot touch a mains connection – provide more insulation, shields, etc. as necessary.

TROUBLE FREE

The following tips will help you to get the best out of Charge-15. First, always check before using the unit that selector switch S3 is set correctly for 2 or 4-cells. Do NOT move S3 between positions while the unit is operating because although the switch will *carry* the operating current it may be damaged if called upon to *switch* it.

Make certain that the cells are correctly inserted – i.e. with the correct polarity in the holder(s). ***A cell inserted the wrong way round is likely to be permanently damaged.***

Avoid covering the unit while it is operating since the heat needs to escape freely. Do not place it on a surface which could be damaged by heat. Note that it is normal for more heat to be produced when charging two cells than four.

If wishing to charge more than one set of cells, wait until the case cools before using it again. ***Never repeat charging of cells in an attempt to increase the amount of charge stored.***

If using S4 (Manual Discharge switch) do not forget to set it back to *Normal* before beginning a charging cycle or the cells will not be charged. If having discharged cells in this way they feel hot, wait for them to cool before beginning a charging cycle.

MEMORY EFFECT

When nickel-cadmium cells are not allowed to discharge completely and have their charge "topped up" repeatedly, they develop a *memory effect*. Thus, if a cell is discharged to one-half of its full rated capacity, it will tend to "remember" this and will only be capable of delivering half a charge. To avoid this effect, nickel-cadmium cells should be completely discharged before charging again.

It may be possible to recover the cells from the memory effect by *completely* discharging the pack then charging several times. After a few such cycles they should begin to "remember" their full capacity and behave normally again. □

Teach-In '93

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Keith Dye B.Eng(Tech)AMIEE and
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Part 11

Teach-In '93 continues a tradition of offering an interesting and thorough tutorial series aimed specifically at the novice or complete beginner in electronics. The series is designed to support those undertaking either GCSE Electronics of GCE Advanced Levels.

LAST month we covered a number of programming topics, and demonstrated some of these on the *Micro Lab*. This month we will look at how microprocessors can interface with external circuits and sensors. We will introduce some more 6502 commands, and give some examples of their use. All the experiments will run on the *Micro Lab*, and some will use the circuits of the *Mini Lab* to act as input and output sensors.

INTERFACING THE MICRO LAB TO THE REAL WORLD

We have previously thought of the Microprocessor as a collection of digital circuits capable of manipulating digital data through input and output ports. The input switches and output l.e.d.s are examples of this digital I/O where they can only be on or off. However, the world we live in is an analogue world where all the forces of nature that affect us are infinitely variable in their makeup.

In earlier parts of Teach-In we measured some of these analogue values using transducers to record light intensity, or temperature. The circuits amplified and conditioned the signals from the transducers to allow us to measure them as analogue voltages on the *Mini Lab* Voltmeter. It is impossible for an all digital microprocessor to record these analogue values without additional circuitry.

Consider an analogue transducer that gives an output signal of 0 to 5 volts for an input temperature range of 0 to 50 degrees C. If this was connected directly to a data input of a microprocessor it would not be able to read all the variations of the signal. Fig. 11.1 shows the digital input characteristic for a typical microprocessor. When the input voltage is below 0·8 volts (8 degrees C) the port sees a logic zero. As the voltage (temperature) increases the logic level of the port is indeterminate – the microprocessor could read the voltage as a logic 1 or logic 0. When the voltage is above 2·0 volts (20 degrees C) the microprocessor will read the input as a logic 1. The result of connecting an analogue signal to a digital input is:

Temperature	Logic Level
0°C to +8°C	0
+8°C to +20°C	undetermined
+20°C to +50°C	1

This is only of limited use. The detection of temperatures below 8 degrees C could be used for a frost thermostat, and the detection of temperatures above +20 degrees C could be used to turn on an air conditioning plant for example. But we could not use the information for recording the actual temperature at any particular time, and it is impossible to determine if the temperature lies between 8 degrees C and 20 degrees C. A new type of circuit is needed that can convert *analogue* signals into a range of *digital* values. This is called an **Analogue to Digital Converter** or **ADC**. Its counterpart is a circuit that converts digital signals to analogue values called a **Digital to Analogue Converter** or **DAC**.

These are the key to allowing a microprocessor or other digital circuits to interface to the real world. Fig. 11.2 shows a typical application where an ADC is needed. The weighing platform could be of the type used in most shops to weigh customer's purchases. When goods are placed on the weighing platform a low level analogue voltage is produced which is proportional to the weight. This is amplified and input to an ADC block where it is converted to a digital signal that can be read by the microprocessor.

In this example the ADC produces 8 bits of digital data and is called an 8 bit ADC. There will be 256 possible output codes, and this determines the minimum *resolution* of the input signal. For an input signal of 0 to 2 volts the resolution of this converter will be 2·0 ÷ 256 = 7·81mV. Converters are available with more output bits that can resolve much smaller voltage changes. If the ADC was a 16 bit converter the resolution would be 2·0 ÷ 65536 = 30·5 *microvolts*.

As the number of bits increases the cost of the converter goes up.

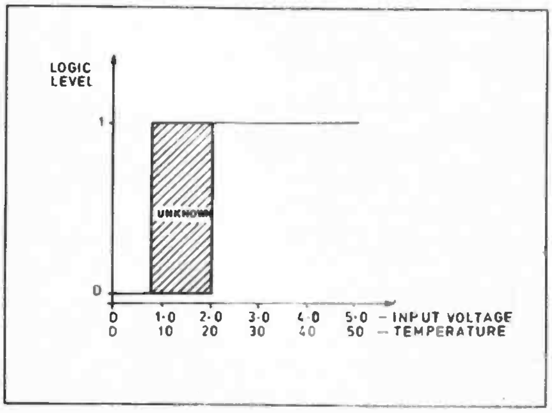


Fig. 11.1. CPU input level.

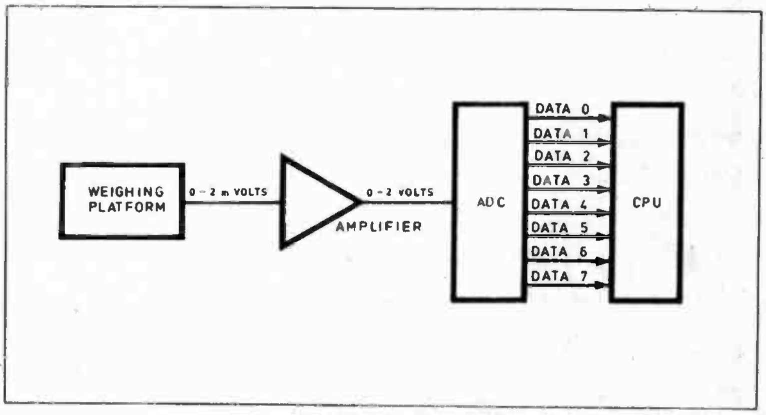


Fig. 11.2. ADC used in weighing application.

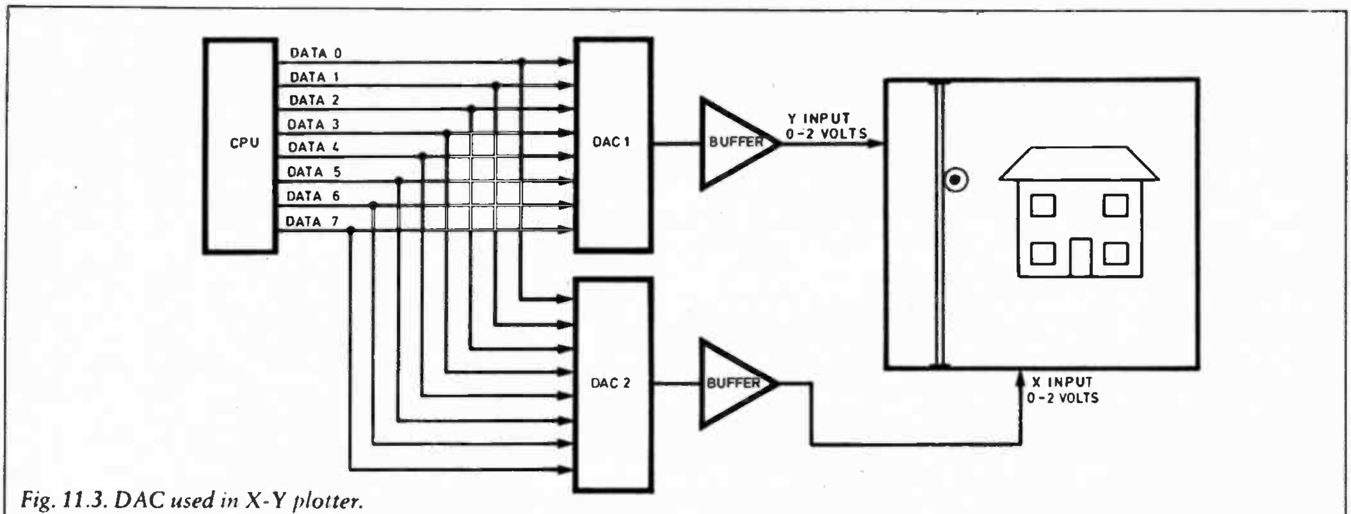


Fig. 11.3. DAC used in X-Y plotter.

A practical limit is reached when the circuit electrical noise in the ADC block exceeds the smallest resolution step size. In practice the limit of resolution is reached with 22 bit converters.

DIGITAL TO ANALOGUE CONVERSION

There is often a need to generate analogue information from a digital input. For instance, Fig. 11.3 shows an application for a DAC. In this example an analogue pen plotter is driven by a microprocessor. The pen plotter requires a 2·0 volt signal for a full scale output of both the X and Y axis. The microprocessor loads digital data into DAC 1 and DAC 2. These produce a 0 to 2·0 volt output signal which is buffered before driving the X and Y channels. By altering the data loaded into the DACs the plotter can draw diagrams held in the CPU's memory. This is a good example of a requirement for high resolution DACs in order to minimise the smallest step that the microprocessor can draw, so the digram will be more accurate.

There are many types of ADC and DAC i.c.s available with internal architecture's optimised to meet different market needs such as low power, high speed, and parallel or serial data output. Have a look at a supplier's catalogue and check out the resolution against price and speed of conversion. As the conversion speeds increase the power consumption of the devices rises due to the increased silicon areas and higher speed clocks used.

The most common type of digital to analogue converter is based on a voltage switching R–2R network. Fig. 11.4 shows a simplified three bit DAC of this type. The digital input drives the switches and a code of 000 will close all the switches to ground giving an output of 0 volts. The voltage reference determines the full scale output of the DAC when all three switches are driven by code 111.

To see how this circuit works a code of 100 will close the Most Significant Bit (MSB) to the reference voltage, and close the other two switches to ground. The output now becomes $V_{ref} \div 2$ as the resistors form a 2:1 attenuator. The combined resistance of all the closed switches becomes 2R and this in conjunction with the MSB 2R acts as a voltage divider.

Similarly as other switches close the output varies due to the different attenuations. If the code is 010 then the output voltage is $V_{ref} \div 4$. In practice the R–2R ladder is followed by a buffer circuit to avoid loading by external circuits. The buffer is often offset above 0 volts to bias the output by ½ step. The output steps for this 3 bit converter are shown in Fig. 11.5 with a ½ step offset. The buffer usually determines the speed at which the DAC can switch from zero to full scale. The actual resistance of R and 2R are unimportant, but their *ratiometric* accuracy determines the accuracy of the DAC. The values are chosen to avoid loading the reference voltage.

Adding additional stages increases the resolution of this type of circuit. The DAC on the *Micro Lab* is an 8 bit converter using the R–2R ladder technique. This is shown in Fig. 11.6. Data is loaded from the data bus when the chip enable signal goes low. The DAC contains an internal 2·56V voltage reference giving a minimum step size of 10mV. The output is buffered by ½ IC17 – a TL072 dual operational amplifier. Resistor R20 is actually a wire link making the amplifier a buffer with a gain of 1. The output can be attenuated by replacing the link with a resistor.

Resistor R18 and capacitor C24 form a simple high pass filter to remove switching noise from the output. This improves the "sound" when audio signals are being outputted.

ANALOGUE TO DIGITAL CONVERTERS

An analogue to digital converter can be made from the switched DAC system described above. Fig. 11.7 shows an 8 bit "tracking" ADC that uses the DAC plus a counter and a window comparator. The input voltage to be measured is compared to the output of the DAC. If DAC output is below the input voltage then the counter is increased and the DAC output increases until it exceeds the input voltage. At this point the counter is switched to "down" mode and the DAC output goes down. When a steady voltage is applied to the ADC input the counter does not oscillate as the comparator has a window of ± ½LSB. When the input voltage changes the ADC tracks the voltage. The counter output provides the digital representation of the analogue input voltage.

This type of converter works well if the input voltage only has a slow rate of change. When a step change is applied – say from zero to full scale – the converter has to clock through every counter value to achieve a balance at the window comparator. A faster scheme is to use a *successive approximation* technique. This is similar to a mechanical balance with a set of weights each twice as big as the previous one up to half the total capacity of the scale.

On weighing an unknown weight the heaviest weight is placed on the balance. If the unknown weight is heavier the next weight is

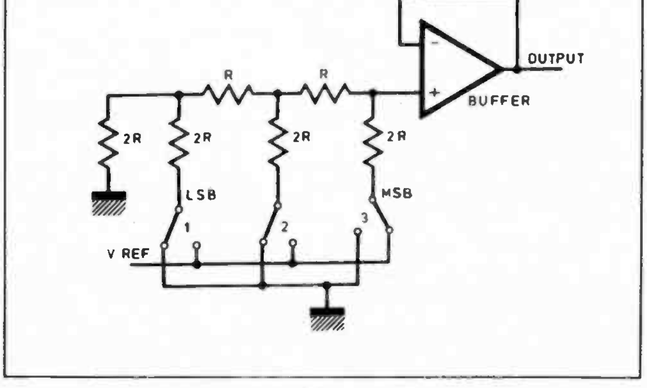


Fig. 11.4. R–3R DAC.

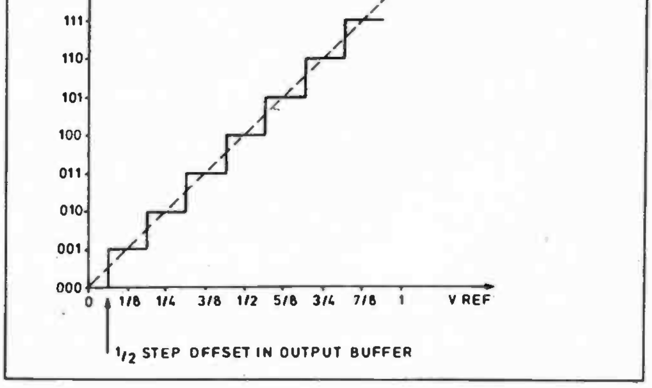


Fig. 11.5. 3-Bit DAC output.

placed on the pan. If the total is now greater than the weight the second weight is taken off and the third placed on the scale. In this way the sum of the remaining weights on the scale equals the unknown weight.

Similarly, the successive approximation converter tries the MSB first followed by the next bit until the DAC output to the comparator "balances" the input voltage. This is shown in Fig. 11.8. The maximum number of clock pulses to measure the input voltage is now 8 (for an 8 bit converter) instead of up to 256! The ADC on the *Micro Lab* is a successive approximation converter, and its circuit diagram is shown in Fig. 11.9.

MICRO LAB ADC

The ADC uses the *Micro Lab* 1 MHz clock for the counter. Again the ZN448 has an internal voltage reference of 2·56 volts. This gives the ADC a 10mV measurement step. The analogue input signals are fed through ½ a TL072P operational amplifier. This is wired as a buffer with a gain of 1. If attenuation of the input is required the R15 link can be replaced with a resistor.

Conversion is started by a CPU write command. After 10 clock periods (additional clocks are needed to set up the converter operation) the data can be read from the output port with a read to address 8020(h). With a 1MHz clock the ADC can operate at a theoretical maximum rate of 100kHz, but additional CPU time is needed to store the data in memory. This allows a maximum read rate of about 50kHz. The ADC needs a negative voltage to operate and this comes from the −5V supply attenuated through R14.

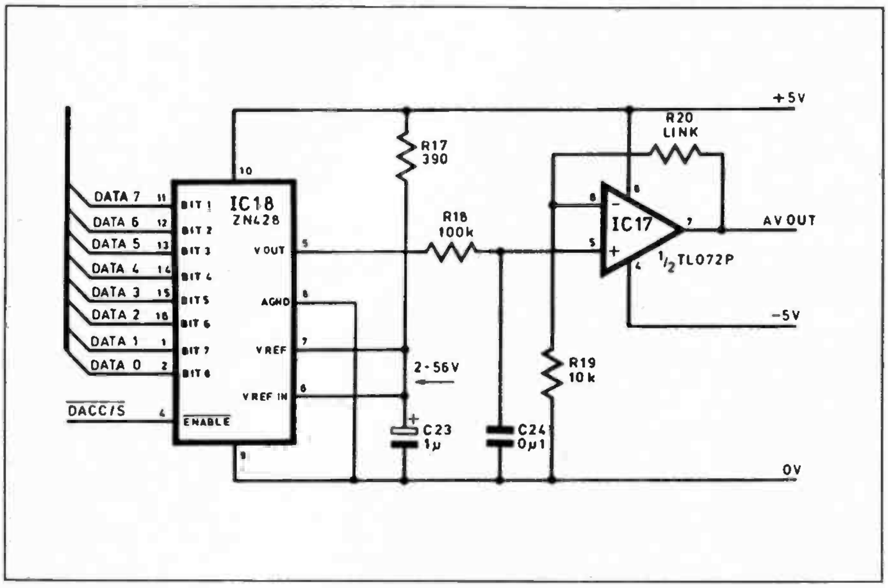


Fig. 11.6. Micro Lab DAC.

DATA LOGGING, MONITORING AND MEASUREMENT

One of the most common uses of computers – particularly smaller systems like the *Micro Lab* – is that of *data logging*. Data logging is simply the measurement and storing of one or more, usually analogue, inputs. The results may then be processed and analysed at a later date. Two common examples are weather stations which record information about rainfall, wind speed and direction, sunlight level, humidity, etc. and temperature monitoring for refrigerated lorries. The data logging equipment may be programmed to give an alarm (or even dial a telephone number) if a measurement goes above or below set limits.

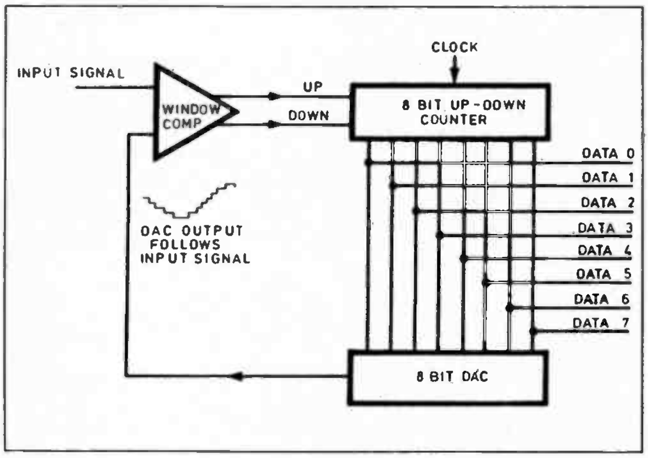


Fig. 11.7. Tracking ADC.

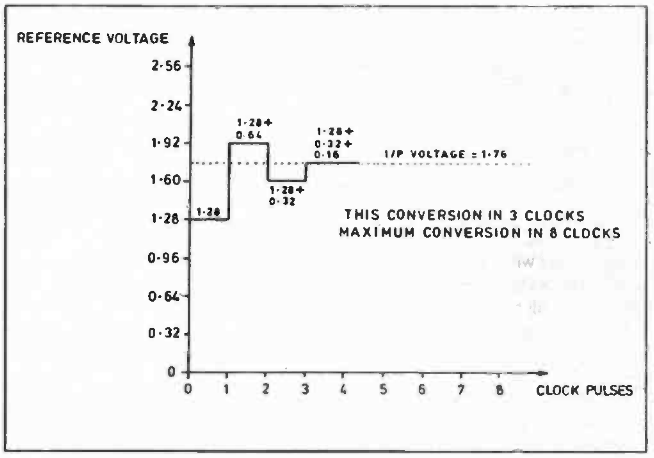


Fig. 11.8. Successive approximation ADC operation.

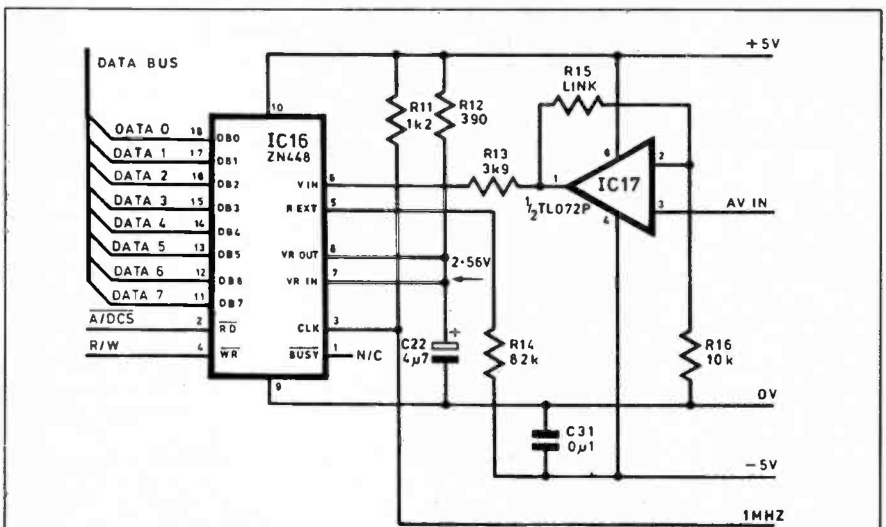


Fig. 11.9. Micro Lab ADC.

Purpose built data logging equipment is often designed to be battery operated and, so, use very low power and high reliability circuits as they may be required to be left unattended for several months – or even years! Also, as a very large number of measurements may need to be stored, several million bytes (mega-bytes or Mb) of memory are usually provided. To increase the amount of data which may be stored, *data compression* techniques are often used.

A simple example of one of these techniques which may be used for measuring slowly changing inputs, stores the difference between the current and the last measurements. So, assume that you have an eight bit A/D converter which is being used to measure sunlight level, and the difference between two samples is between −8 and +7, then you could store this number in four bits. This doubles the number of samples which you can store.

Fig. 11.10. Demonstration Program 5.

```
81C2                ;**********************************************************************
81C2                ;***                                                                ***
81C2                ;***  Everyday Electronics Micro-Lab                                ***
81C2                ;***                                                                ***
81C2                ;***     Name:            Demonstration 5                          ***
81C2                ;***     Version:         1.0                                       ***
81C2                ;***     Author:          Geoff MacDonald                           ***
81C2                ;***     Date:            13/01/1993                                ***
81C2                ;***     Last Update:                                               ***
81C2                ;***                                                                ***
81C2                ;**********************************************************************
81C2
81C2                                ;Read sixty values from the analogue input at one second
81C2                                ;intervals and store them in a table in RAM between
81C2                                ;$0200 and $023C.
81C2
81C2  A900    D_DEMO5:    LDA    #0          ;Point to start of table
81C4  8590                STA    $90
81C6  A200    DEMO5A:     LDX    #0          ;Position cursor to left side
81C8  A001                LDY    #1          ;of bottom row,
81CA  A900                LDA    #0          ;with cursor off
81CC  200900              JSR    CURSOR
81CF  A590                LDA    $90         ;Display sample number
81D1  202400              JSR    HEXOUT
81D4  A920                LDA    #$20        ;Display a space
81D6  200600              JSR    OPCHAR
81D9  8DFFFF              STA    $FFFF       ;Initiate A/D conversion
81DC  A00A                LDY    #10         ;Delay
81DE  88      DEMO5B:     DEY
81DF  D0FD                BNE    DEMO5B
81E1  AD2080              LDA    AIN         ;Read analogue input
81E4  A690                LDX    $90         ;Store it in the table
81E6  9D0002              STA    $0200,X
81E9  202400              JSR    HEXOUT      ;Display it on the LCD
81EC  A964                LDA    #100        ;Delay for one second
81EE  201800              JSR    DELAY
81F1  E690                INC    $90         ;Point to next position in the table
81F3  E03B                CPX    #59
81F5  D0CF                BNE    DEMO5A      ;Repeat for sixty values
81F7  00                  BRK                ;Terminate
```

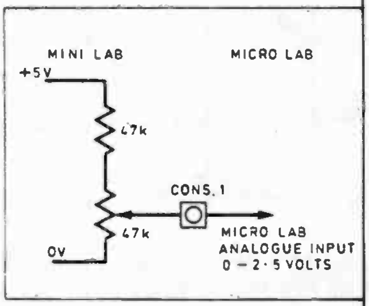


Fig. 11.11. 0-2·5 volt source – data logging simulator.

Suppose the system measures light level between 0 and 255 every second. Over a period of ten seconds the following results are obtained:

40, 46, 48, 47, 49, 45, 40, 37, 34, 30, 33

The differences between successive values are:

+6, +2, −1, +2, −4, −5, −3, −3, −4, +3

The program would store the first measurement as normal, followed by the differences. In hexadecimal, this would be:

28, 62, F2, CB, DD, C3

(Since in hex. −1 = F, −2 = E, −3 = D, −4 = C, −5 = B . . .)

Another technique, called *run length encoding* (RLE) may be used again for data which changes very slowly. When using this technique the program keeps a count of the number of measurements which have not changed and stores a measurement value followed by the number of times which it occurred.

Suppose the following measurements are obtained:

40, 40, 40, 41, 42, 43, 43, 43, 43, 43, 43

This would be stored using RLE as:

40, 3, 41, 1, 42, 1, 43, 6

Obviously, if the data changes rapidly, then this technique would result in more memory being needed, not less!

Real systems often use several different techniques for data compression and analyse the incoming measurements to determine the most effective.

The *Micro Lab* contains a demonstration data logging program – Fig. 11.10 Demonstration 5 – which records the value of the analogue input every second over a period of one minute. As there is more than enough memory contained on board, no data compression techniques are used (this also makes it easier for you to examine the data afterwards). To use this program, you will need to connect a circuit which will place a varying voltage between 0V and 2·5V on the analogue input. A suitable circuit is shown in Fig. 11.11. This circuit uses a potentiometer to change the voltage, but you could use a thermistor or l.d.r. but you will need to change other component values to get the desired output voltage swing.

The demonstration program firstly sets up a pointer to address 0200h, which is the first address where the data will be stored. Next, it reads the analogue port and stores the value at the next free location in memory, then waits for one second. The memory pointer is then incremented by one and, if it is less than 60 (or 3Ch) it jumps back to read the port again. The measurement number and value are displayed in hexadecimal on the l.d.c. as the program runs.

When the program has finished running, you can inspect the results using the **MOD**ify command by entering:

MODIFY 200

The first eight readings will be displayed on the l.c.d. You may display the remainder of the data using the ENTER and DEL keys as described in the *Micro Lab* manual.

If you wish to retain the data after the *Micro Lab* has been switched off, remember to place the memory link on **BATT.**

As an exercise, you could re-type this program into RAM and modify it to take more readings. If you then connect the analogue input to a light dependent resistor via a suitable circuit, you could have it monitor light levels over several minutes or hours.

Readers who have followed all the *Teach-In* articles may like to try adapting the analogue circuits used to measure temperature and light to record the results on the *Micro Lab.*

SOUND SAMPLING

Another very common use to which computers are put is for *sound sampling.* This is simply using fast data logging to record sound into a computer memory. The sound may then be manipulated, looped, reversed, echoed, reverbed, chopped, phased, chorused and lots of other terms used by the music industry. Sound samples are frequently used by musical synthesisers and drum machines (most records with "OOOh's", "AAAh's" and "OH YEAH!'s" are produced using sampling keyboards). Currently, the most popular use of digital sound sampling is in the compact disc. Sound is recorded as digital information that is read and converted back into analogue voltages by the CD player. Computer game sound effects and computerised speech are also common uses for sound sampling techniques.

The problem with sound sampling is the amount of storage space needed. The sound must be sampled at a minimum of twice the highest frequency of the input, otherwise *aliasing* occurs. To demonstrate aliasing, imagine a simple sine wave at a frequency of 10kHz sampled at a frequency of 9kHz (see Fig. 11.12). When the stored sample is played back, the output has a frequency of 1kHz,

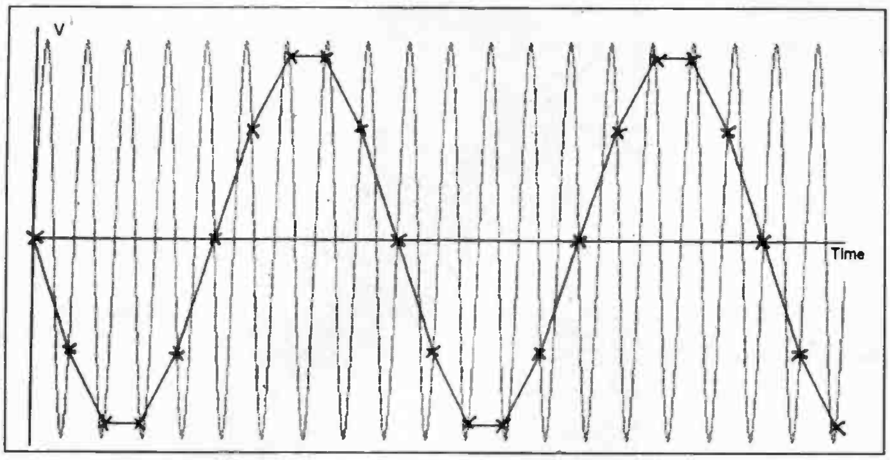


Fig. 11.12. Aliasing – A 10kHz signal sampled at 9kHz (x = sample) gives a 1kHz output signal.

and all the high frequency information is lost. To accurately record signals that avoid aliasing samples are taken at least twice as fast as the highest frequency in the signal.

To get high quality sound samples we must sample at a minimum of 40kHz (this gives a maximum input frequency of 20kHz which is about the highest a human ear can pick up). CD sound is recorded at 44·1kHz to ensure all audible signals are recorded.

It is also a good idea to use 16 bit samples to remove *quantisation noise*. This is noise produced due to the maximum number of output voltages being a fixed finite value (see Fig. 11.13). With 8 bit samples, the number of possible output voltages is 256 which can produce some noise when replayed. With 16 bits, the number of possible output voltages is 65536, the noise produced by the "steps" is very small compared to the audio signal, and is all but inaudible.

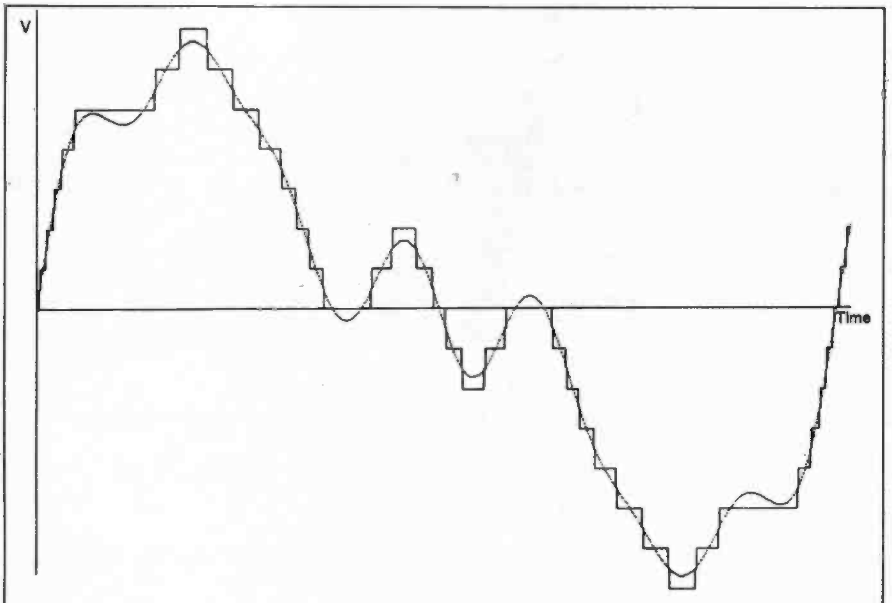


Fig. 11.13a. Waveform quantisation with 16 Levels.

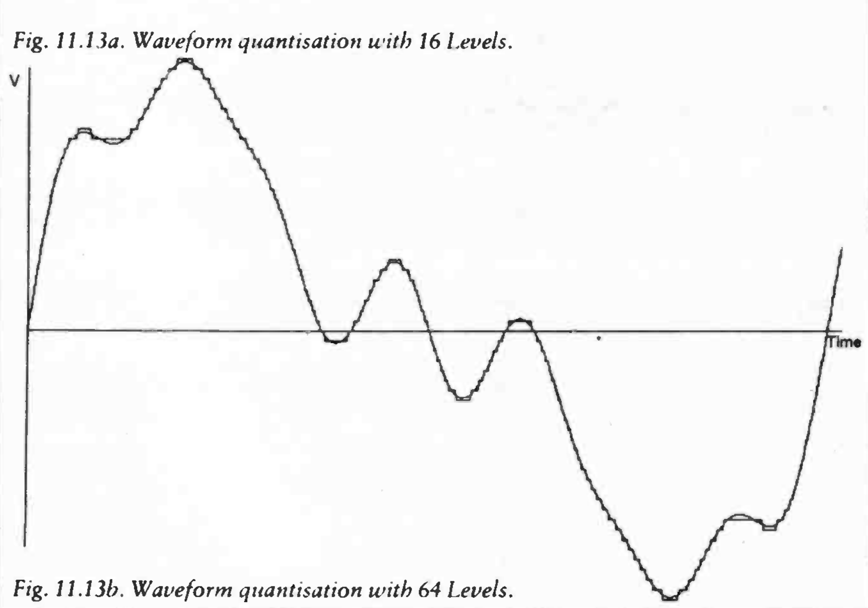


Fig. 11.13b. Waveform quantisation with 64 Levels.

So, in one second of monophonic CD quality sound, we need to take 44,100 samples each of 16 bits, which is 88,200 bytes of data – nearly three times the amount of memory contained on the *Micro Lab*! The optical CD used for audio can store up to 650Mbytes of data, allowing over 60 minutes of high quality stereo sound to be listened to. Unfortunately, it is difficult to use much data compression due to the time taken to decompress the data. This makes high quality sound sampling hardware quite expensive due to the large amounts of memory required. Lower quality systems sample at lower rates (12kHz is adequate for speech) and use 8 bits of data.

SPEECH DEMO

The *Micro Lab* has two demonstration routines to perform sound sampling and playback. These work with a sample rate of roughly 8kHz, with 8 bit samples and no compression techniques – which is a bit crackly. Firstly, connect up a microphone and amplifier circuit on your *Mini Lab* as shown in Fig. 11.14. Note that both the input and output circuits have simple filters on them to cut out any frequencies above 4kHz to reduce aliasing. Next, run Demonstration Program 8, Fig. 11.15, and speak into the microphone – you've got about four seconds – the speech is now being recorded into the RAM. Now, run Demonstration Program 9, Fig. 11.16, and the recorded speech is played back!

Both programs are quite simple. The recorder program sets up a pointer to the start of user RAM (0200h) then reads the analogue input port and stores the value returned at the currently pointed to location. It then delays for a short time – to get a sample rate of about 8kHz – and increments the pointer by one, before looping back. The replay program does something similar except that it reads the value from RAM and sends it to the analogue output port.

You could enter these programs in RAM (but you would need to store them at location 0100h, or set the start of the sample storage area to 0300h, otherwise the programs will be overwritten by the sample) and change the delay times to alter the pitch of the playback or sample at a higher frequency. Sampling at a higher rate will improve the quality, while sampling at a lower rate will give a longer sample time.

Next, its time to look at more CPU instructions, and discover some more programming techniques. Fig. 11.17 gives some more 6502 instructions, and adds to those given last month. Remember that a $ in front of a number, or a h or (H) after indicates that the number is in hexadecimal format.

STACKS AND SUBROUTINES

Some of the programs which we have written so far use a *Jump to Subroutine* (JSR) instruction to call routines within the Micro Lab monitor to do things such as writing to the l.c.d. This instruction tells the 6502 to run a section of program (called a *subroutine*) from the specified address until a *Return from Subroutine* (RTS) instruction is encountered. The 6502 should then jump back to the instruction after the JSR. As a subroutine may be called from anywhere in your programs, the CPU needs to store the address of the JSR which called it so that it knows where to jump back to. The area of memory where the address is stored is called a *stack*. The 6502 always stores the stack in page one of memory (0100h to 01FFh), but some processors allow you to position the stack anywhere. The stack is also used as a

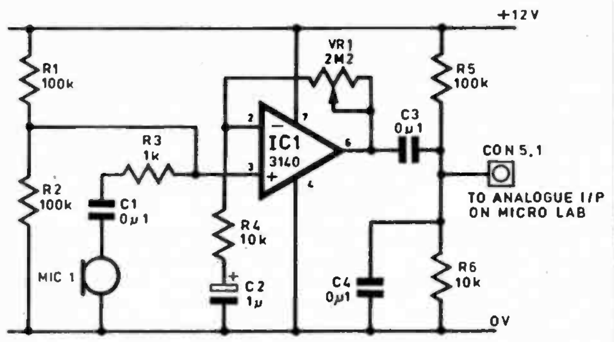


Fig. 11.14a Microphone I/P circuit.

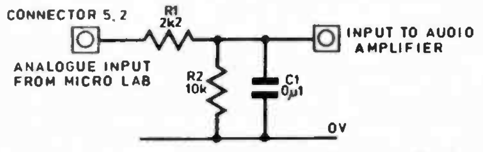


Fig. 11.14b. Audio output circuit.

temporary store for numbers and registers and sometimes for passing *parameters* to routines.

A stack is simply a list of numbers of variable length. The CPU uses a register called the *stack pointer* to point to the next memory location where a number is to be stored. When a number is pushed onto the stack, it is stored at the location pointed to by the stack pointer and the stack pointer is incremented by one. When a number is pulled (or popped) from the stack, the stack pointer is decremented by one and the number is read from the memory location now pointed to. This is called a *Last In First Out* (LIFO) stack. For example:

> Assuming that the stack is empty at the start, the stack pointer (SP) equals FFh.
>
> After pushing the value 12h, the stack looks like this:
> (SP = FEh) Stack = 12h
>
> Pushing 34h gives:
> (SP = FDh) Stack = 12h, 34h
>
> Pushing 56h gives:
> (SP = FCh) Stack = 12h, 34h, 56h

DELAYS

It is often useful to include delays in your programs – especially when writing in machine code which is quite fast. Most delays are included to give the user of your programs time to see something happening, but there are many other times when you will need to slow your programs down.

The easiest way to produce a delay is to get the computer to count down from a particular value in a loop. The bigger the value, the longer the delay. The example below will produce a very short delay by loading the IX register with 255 (FFh) and repeatedly decreasing it by one (with the DEX instruction) until it becomes zero:

```
0200 A2 FF      LDX  #$FF     ;Set delay length
0202 CA         DEX           ;IX = IX - 1
0203 D0 FD      BNE  $0202    ;Loop until IX = 0
0205 00         BRK           ;Stop program
```

The main part of this program are the DEX and BNE lines which are both executed a total of 255 times. With a 1MHz 6502, the DEX instruction takes 2µS to execute and the BNE instruction takes 2µS. This gives a total delay time of 1.02mS (4µS x 255). This is not a very long time! A simple delay of this sort is useful for setting the speed of some tasks but often longer delays are required. An easy way of producing a delay of up to about 1/2 second is to use the IY register to count down from 255 with the above routine between each count:

```
0200 A0 FF      LDY #$FF      ; IY = 255
0202 A2 FF      LDX #$FF      ; IX = 255
0203 CA         DEX           ; IX = IX - 1
0204 D0 FD      BNE $0203     ; Loop if not 0
0206 88         DEY           ; IY = IY - 1
0208 D0 FA      BNE $0202     ; Loop if not 0
020A 00         BRK           ; Stop program
```

You can get even longer delays by using the accumulator as a third counter, with the above routine between each count. You could then have IX and IY loaded with values to produce a known delay time (say 0·01S). It would be very easy to produce known long delays by setting the accumulator before calling the delay (e.g. LDA #200 would give a delay of two seconds, LDA #50 would give a delay of ½ second). This is how the monitor **DELAY** subroutine in the *Micro Lab* works.

Fig. 11.15. Demonstration Program 8

```
82B1                  ;*****************************************************************
82B1                  ;***                                                           ***
82B1                  ;***  Everyday Electronics Micro-Lab                           ***
82B1                  ;***                                                           ***
82B1                  ;***     Name:           Demonstration 8                       ***
82B1                  ;***     Version:        1.0                                   ***
82B1                  ;***     Author:         Geoff MacDonald                       ***
82B1                  ;***     Date:           18/01/1993                            ***
82B1                  ;***     Last Update:                                          ***
82B1                  ;***                                                           ***
82B1                  ;*****************************************************************
82B1
82B1                              ;Fills the RAM, beginning at address $0200, with
82B1                              ;samples taken from the analogue input at a rate
82B1                              ;of 8.0645kHz (4 seconds of data)
82B1
82B1  A900      D_DEMO8:   LDA    #$00          ;Set up table start address
82B3  8590                 STA    $90
82B5  A902                 LDA    #$02
82B7  8591                 STA    $91
82B9  A000                 LDY    #$00
82BB  8DFFFF    DEMO8A:    STA    $FFFF         ;4uS     ;Initiate analogue conversion
82BE  A217                 LDX    #23           ;6uS     ;92uS Delay
82C0  CA        DEMO8B:    DEX
82C1  D0FD                 BNE    DEMO8B        ;98uS
82C3  AD2080               LDA    AIN           ;102uS   ;Get analogue input
82C6  9190                 STA    ($90),Y       ;108uS   ;Store it in the table
82C8  18                   CLC                  ;110uS
82C9  A590                 LDA    $90           ;112uS
82CB  6901                 ADC    #$01          ;114uS
82CD  8590                 STA    $90           ;116uS
82CF  A591                 LDA    $91           ;118uS
82D1  6900                 ADC    #$00          ;120uS
82D3  8591                 STA    $91           ;122uS
82D5  10E4                 BPL    DEMO8A        ;124uS
82D7  00                   BRK
```

Pulling from the stack into the accumulator:
(SP = FDh) (Acc = 56h) Stack = 12h, 34h

Pulling again gives:
(SP = FEh) (Acc = 34h) Stack = 12h

Pulling again gives:
(SP = FFh) (Acc = 12h) Stack = <Empty>

If you have a *Micro Lab*, you can see this happening by typing in the following program and running it with single stepping switched on. Single stepping makes the program stop after every instruction and the l.c.d. shows you all the CPU registers. You can see the program counter, accumulator and stack pointer changing with each operation.

Unfortunately, there are four 6502 instructions that escape the single stepping hardware! These are:

PHA (Push the accumulator onto the stack)
PLA (Pull the accumulator from the stack)
PHP (Push the PSW onto the stack)
PLP (Pull the PSW from the stack)

The single stepping command skips over these instructions and stops on the following instruction. A solution is to enter a NOP instruction immediately after each of these instructions. The l.c.d. will now show the CPU registers after the instruction has executed.

```
0200 A9 12    LDA #$12    ;Push 12h onto
0202 48       PHA         ;the stack.
0203 EA       NOP
0204 A9 34    LDA #$34    ;Push 34h.
0206 48       PHA
0207 EA       NOP
0208 A9 56    LDA #$56    ;Push 56h.
020A 48       PHA
020B EA       NOP
020C 68       PLA         ;Pull into Acc.
020D EA       NOP
020E 68       PLA         ;Pull into Acc.
020F EA       NOP
020B 68       PLA         ;Pull into Acc.
020C 00       BRK         ;End of program.
```

When a subroutine is called, the CPU first pushes two bytes onto the stack – the low and high bytes of the calling address. Next, it loads the program counter with the address of the subroutine, making the program jump to this address. When an RTS instruction is encountered, the top two bytes of the stack are pulled and stored in the program counter, this makes the program jump back to the calling address. You should, therefore, always take care when using the stack to pull the same number of bytes as you push otherwise when an RTS instruction is executed the wrong address will be pulled and your program will crash.

As values pulled from the stack are the most recently pushed, it is possible to call subroutines from within subroutines or even to have a subroutine call itself (this is called *recursion*). An example of this is in the **STRING** subroutine of the *Micro Lab* monitor. This subroutine is used to output a string of characters to the l.c.d. It first loads the accumulator with the ASCII value of the first character to display and then calls the **OPCHAR** subroutine which displays the character on the l.c.d. It then gets the ASCII value of the next character and calls the **OPCHAR** routine again.

Owners of the *Micro Lab* can see this happening by typing in the following program and running it with single stepping turned on. The program simply loads the accumulator with 00h then calls a subroutine which loads the accumulator with 01h. This subroutine then calls another subroutine which loads the accumulator with 02h. You can see the program counter, stack pointer and accumulator changing as each instruction is executed.

```
0200 A9 00      LDA #$00     ;Main program
0202 20 06 02   JSR $0206
0205 00         BRK

0206 A9 01      LDA #$01     ;Routine number 1
0208 20 0C 02   JSR $020C
020B 60         RTS

020C A9 02      LDA #$02     ;Routine number 2
020E 60         RTS
```

INTERRUPTS

There are two pins on the 6502, one called *Non-Maskable Interrupt* (NMI) and the other called *Interrupt Request* (IRQ). When the voltage applied to one of these pins changes from 5V to 0V, an *interrupt* occurs. The processor stops executing the main program (pushing the PSW and PC registers onto the stack) and jumps to an *interrupt*

Fig. 11.16. Demonstration Program 9.

```
82D8                ;**************************************************************************
82D8                ;***                                                                   ***
82D8                ;***  Everyday Electronics Micro-Lab                                   ***
82D8                ;***                                                                   ***
82D8                ;***     Name:            Demonstration 9                              ***
82D8                ;***     Version:         1.0                                          ***
82D8                ;***     Author:          Geoff MacDonald                              ***
82D8                ;***     Date:            18/01/1993                                   ***
82D8                ;***     Last Update:                                                  ***
82D8                ;***                                                                   ***
82D8                ;**************************************************************************
82D8
82D8                            ;Reads data from RAM, beginning at address $0200,
82D8                            ;and sends each byte to the analogue output at a
82D8                            ;rate of 8.0645kHz (4 seconds of data)
82D8
82D8  A900      D_DEMO9:        LDA     #$00        ;Set up table start address
82DA  8590                      STA     $90
82DC  A902                      LDA     #$02
82DE  8591                      STA     $91
82E0  A000                      LDY     #$00
82E2  A218      DEMO9A:         LDX     #24         ;2uS    ;92uS Delay
82E4  CA        DEMO9B:         DEX
82E5  D0FD                      BNE     DEMO9B      ;98uS
82E7  B190                      LDA     ($90),Y     ;104uS  ;Get analogue input
82E9  8D3080                    STA     AOUT        ;108uS  ;Store it in the table
82EC  18                        CLC                 ;110uS
82ED  A590                      LDA     $90         ;112uS
82EF  6901                      ADC     #$01        ;114uS
82F1  8590                      STA     $90         ;116uS
82F3  A591                      LDA     $91         ;118uS
82F5  6900                      ADC     #$00        ;120uS
82F7  8591                      STA     $91         ;122uS
82F9  10E7                      BPL     DEMO9A      ;124uS
82FB  A900                      LDA     #$00        ;Set output voltage to 0V
82FD  8D3080                    STA     AOUT
8300  00                        BRK
```

Figure 11.17 - Additional 6502 Instructions

ADC - Add with Carry NV-BDIZC
xx----xx

Adds the contents of the memory address or immediate data to the accumulator and the carry bit. The result is placed in the accumulator. The CLC instruction can be used before ADC to add without carry.

Address Mode	Op-Code	Example	
Immediate	69	69 20	ADC #20h
Absolute	6D	6D 34 12	ADC 1234h
Zero Page	65	65 20	ADC 20h
(Indirect,X)	61	61 20	ADC (20h,X)
(Indirect),Y	71	71 20	ADC (20h),Y
Zero Page,X	75	75 20	ADC 20h,X
Absolute,X	7D	7D 34 12	ADC 1234h,X
Absolute,Y	79	79 34 12	ADC 1234h,Y

AND - Logical AND NV-BDIZC
x-----x-

Performs a logical AND of the memory address or immediate data and the accumulator. The result is stored in the accumulator.

Address Mode	Op-Code	Example	
Immediate	29	29 20	AND #20h
Absolute	2D	2D 34 12	AND 1234h
Zero Page	25	25 20	AND 20h
(Indirect,X)	21	21 20	AND (20h,X)
(Indirect),Y	31	31 20	AND (20h),Y
Zero Page,X	35	32 20	AND 20h,X
Absolute,X	3D	3D 34 12	AND 1234h,X
Absolute,Y	39	39 34 12	AND 1234h,Y

ASL - Arithmetic Shift Left NV-BDIZC
x-----xx

Shifts the contemts of the accumulator or memory location left by one bit. Bit 7 is placed in the carry bit, and bit 0 is set to 0.

Address Mode	Op-Code	Example	
Absolute	0E	0E 34 12	ASL 1234h
Zero Page	06	06 20	ASL 20h
Accumulator	0A	0A	ASL A
Zero Page,X	16	16 20	ASL 20h,Y
Absolute,X	1E	1E 34 12	ASL 1234h,X

BCS - Branch on Carry Set NV-BDIZC

Tests the carry flag for 1. If set the program will branch forward or backwards by the number of bytes specified. If clear the next program instruction is executed. Displacement range from + 127 to -128 from the next instruction after BCS.

Address Mode	Op-Code	Example	
Relative	B0	B0 20	BCS PC + 20h

BIT - Test Accumulator Against Memory Bits NV-BDIZC
xx----x-

Performs a logical AND between the accumulator and specified memory location. If the memory and accumulator are not equal the zero (Z) flag is set to 1. If the contents are equal the Z flag is set to 0, and the V flag is set equal to bit 6 of the memory location, and the N flag is set equal to bit 7. The accumulator remains unchanged.

Address Mode	Op-Code	Example	
Absolute	2C	2C 34 21	BIT 1234h
Zero Page	24	24 20	BIT 20h

BMI - Branch on Minus NV-BDIZC

Tests the N flag for 1. If set the program will branch forward or backwards by the number of bytes specified. If clear the next program instruction is executed. Displacement range from + 127 to -128 from the next instruction after BMI.

Address Mode	Op-Code	Example	
Relative	30	30 20	BMI PC + 20h

BPL - Branch on Plus NV-BDIZC

Tests the N flag for 0. If clear the program will branch forward or backwards by the number of bytes specified. If set the next program instruction is executed. Displacement range from + 127 to -128 from the next instruction after BPL.

Address Mode	Op-Code	Example	
Relative	10	10 20	BPL PC + 20h

BVC - Branch on Overflow Clear NV-BD1ZC

Tests the V flag for 0. If clear the program will branch forward or backwards by the number of bytes specified. If set the next program instruction is executed. Displacement range from + 127 to -128 from the next instruction after BVC.

Address Mode	Op-Code	Example	
Relative	50	50 20	BVC PC + 20h

BVS - Branch on Overflow Set NV-BDIZC

Tests the V flag for 1. If set the program will branch forward or backwards by the number of bytes specified. If clear the next program instruction is executed. Displacement range from + 127 to -128 from the next instruction after BVS.

Address Mode	Op-Code	Example	
Relative	70	70 20	BVS PC + 20h

CLC - Clear Carry Flag NV-BDIZC
-------0

Clears the C flag. This instruction is used before ADC to allow addition without a carry.

Address Mode	Op-Code	Example	
Implied	18	18	CLC

CLD - Clear the Decimal Flag NV-BDIZC
----0---

Clears the D flag, and allows ADC and SBC operations to be performed in binary.

Address Mode	Op-Code	Example	
Implied	D8	D8'	CLD

CLI - Clear Interrupt Disable Flag NV-BDIZC
-----0--

Enables interrupts. This flag should always be cleared during an interrupt routine to enable further interrupts.

Address Mode	Op-Code	Example	
Implied	58	58	CLI

CLV - Clear Overflow Flag NV-BDIZC
-0------

Clears the V flag.

Address Mode	Op-Code	Example	
Implied	B8	B8	CLV

CMP - Compare Accumulator NV-BDIZC
x----xx

Compares the contents of the specified memory or immediate data with the accumulator. If the result is zero Z is set. If bit 7 = 1 (negative) then N is set to 1. If the accumulator equals or is greater than the data (negative) the C flag is set. The memory and accumulator contents are unchanged.

Address Mode	Op-Code	Example	
Immediate	C9	C9 20	CMP #20h
Absolute	CD	CD 34 12	CMP 1234h
Zero Page	C5	C5 20	CMP 20h
(Indirect,X)	C1	C1 20	CMP (20h,X)
(Indirect),Y	D1	D1 20	CMP (20h),Y
Zero Page,X	D5	D5 20	CMP 20h,X
Absolute,X	DD	DD 34 12	CMP 1234h,X
Absolute,Y	D9	D9 34 12	CMP 1234h,Y

CPX - Compare to X Register NV-BDIZC
x-----xx

Compares the contents of the specified memory or immediate data with the X register. If the result is zero Z is set. If bit 7 = 1 (negative) then N is set to 1. If the register equals or is greater than the data (negative) the C flag is set. The memory and X contents are unchanged.

Address Mode	Op-Code	Example	
Immediate	C9	C9 20	CPX #20h
Absolute	CD	CD 34 12	CPX 1234h
Zero Page	C5	C5 20	CPX 20h

DEC - Decrement NV-BDIZC
x-----x-

Subtracts 1 from the memory location and stores the results in the memory location.

Address Mode	Op-Code	Example	
Absolute	CE	CE 34 12	DEC 1234h
Zero Page	C6	C6 20	DEC 20h
Zero Page,X	D6	D6 20	DEC 20h,X
Absolute,X	DE	DE 34 12	DEC 1234h,X

DEY - Decrement the Y Register NV-BDIZC
x-----x-

Decrements 1 from the Y register

Address Mode	Op-Code	Example	
Implied	88	88	DEY

Continued on next page

EOR – Exclusive-OR NV-BDIZC
x-----x-

Exclusive-ORs the accumulator with the specified data, and places the result in the accumulator.

Address Mode	Op-Code	Example	
Immediate	49	49 20	EOR #20h
Absolute	4D	4D 34 12	EOR 1234h
Zero Page	45	45 20	EOR 20h
(Indirect,X)	41	41 20	EOR (20h,X)
(Indirect),Y	51	51 20	EOR (20h),Y
Zero Page,X	55	55 20	EOR 20h,X
Absolute,X	5D	5D 34 12	EOR 1234h,X
Absolute,Y	59	59 34 12	EOR 1234h,Y

INC – Increment Memory NV-BDIZC
x-----x-

Adds 1 to the contents of the memory and stores the result in the memory.

Address Mode	Op-Code	Example	
Absolute	EE	EE 34 12	INC 1234h
Zero Page	E6	E6 20	INC 20h
Zero Page,X	F6	F6 20	INC 20h,X
Absolute,X	FE	FE 34 12	INC 1234h,X

INX – Increment X Register NV-BDIZC
x-----x-

Adds 1 to the contents of the X register.

Address Mode	Op-Code	Example	
Implied	E8	E8	INX

NOP – No Operation NV-BDIZC

This instruction does nothing, but takes two machine cycles to process. It is useful for timing loops.

Address Mode	Op-Code	Example	
Implied	EA	EA	NOP

ORA – Inclusive OR with Accumulator NV-BDIZC
x-----x-

Inclusive-ORs the accumulator with memory and places the result in the accumulator.

Address Mode	Op-Code	Example	
Immediate	09	09 20	ORA #20h
Absolute	0D	0D 34 12	ORA 1234h
Zero Page	05	05 20	ORA 20h
(Indirect,X)	01	01 20	ORA (20h,X)
(Indirect),Y	11	11 20	ORA (20h),Y
Zero Page,X	15	15 20	ORA 20h,X
Absolute,X	1D	1D 34 12	ORA 1234h,X
Absolute,Y	19	19 34 12	ORA 1234h,Y

PHP – Push Processor Status onto Stack NV-BDIZC

Copies the contents of the status register onto the stack and decrements the stack pointer.

Address Mode	Op-Code	Example	
Implied	08	08	PHP

PLP – Pull Processor Status from Stack NV-BDIZC
xx-xxxxx

Loads the top byte from the stack into the status register and increments the stack pointer. All flags are restored to the saved condition.

Address Mode	Op-Code	Example	
Implied	28	28	PLP

ROL – Rotate Left 1 Bit NV-BDIZC
x-----xx

Rotates the contents of the accumulator or address left by 1 bit. The C flag is transferred to bit 0 and bit 7 is transferred into the C flag.

Address Mode	Op-Code	Example	
Absolute	2E	2E 34 12	ROL 1234h
Zero Page	26	26 20	ROL 20h
Accumulator	2A	2A	ROL A
Zero Page,X	36	36 20	ROL 20h,X
Absolute,X	3E	3E 34 12	ROL 1234h,X

ROR – Rotate Right 1 Bit NV-BDIZC
x-----xx

Rotates the contents of the accumulator or address right by 1 bit. The C flag is transferred to bit 0 and bit 7 is transferred into the C flag.

Address Mode	Op-Code	Example	
Absolute	6E	6E 34 12	ROR 1234h
Zero Page	66	66 20	ROR 20h
Accumulator	6A	6A	ROR A
Zero Page,X	76	76 20	ROR 20h,X
Absolute,X	7E	7E 34 12	ROR 1234h,X

RTI – Return from Interrupt NV-BDIZC
xx-xxxxx

Restores the program counter and status register from the stack after processing an interrupt routine. The stack pointer is incremented to point at the next stored value.

Address Mode	Op-Code	Example	
Implied	40	40	RTI

RTS – Return from Subroutine NV-BDIZC

Restores the program counter from the stack and increments the stack pointer.

Address Mode	Op-Code	Example	
Implied	60	60	RTS

SBC – Subtract with Carry NV-BDIZC
xx----xx

Subtracts the data from the accumulator with borrow. The result is saved in the accumulator. Operates in Decimal or Binary modes.

Address Mode	Op-Code	Example	
Immediate	E9	E9 20	SBC #20h
Absolute	ED	ED 34 12	SBC 1234h
Zero Page	E5	E5 20	SBC 20h
(Indirect,X)	E1	E1 20	SBC (20h,X)
(Indirect),Y	F1	F1 20	SBC (20h),Y
Zero Page,X	F5	F5 20	SBC 20h,X
Absolute,X	FD	FD 34 12	SBC 1234h,X
Absolute,Y	F9	F9 34 12	SBC 1234h,Y

SEC – Set Carry Flag NV-BDIZC
-------1

Sets the C flag to 1.

Address Mode	Op-Code	Example	
Implied	38	38	SEC

SED – Set Decimal Mode Flag NV-BDIZC
----1---

Sets the D flag to 1. ADC and SBC will be performed in Binary Coded Decimal until the CLD is executed.

Address Mode	Op-Code	Example	
Implied	F8	F8	SED

SEI – Set Interrupt Disable Flag NV-BDIZC
-----1--

Sets the interrupt bit to 1 which disables the interrupts. Use when interrupts are not required.

Address Mode	Op-Code	Example	
Implied	78	78	SEI

STX – Store X in Memory NV-BDIZC

Stores a copy of the X register at the specified memory location.

Address Mode	Op-Code	Example	
Absolute	8E	8E 34 12	STX 1234h
Zero Page	86	86 20	STX 20h
Zero Page,Y	96	96 20	STX 20h,Y

STY – Store Y in Memory NV-BDIZC

Stores a copy of the Y register at the specified memory location.

Address Mode	Op-Code	Example	
Absolute	8C	8C 34 12	STY 1234h
Zero Page	84	84 20	STY 20h
Zero Page,X	94	94 20	STY 20h,X

TAX – Transfer Accumulator to X NV-BDIZC
x-----x-

Copies the contents of the accumulator to the X register.

Address Mode	Op-Code	Example	
Implied	AA	AA	TAX

TAY – Transfer Accumulator to Y NV-BDIZC
x-----x-

Copies the contents of the accumulator to the Y register.

Address Mode	Op-Code	Example	
Implied	A8	A8	TAY

TSX – Transfer Stack Pointer to X NV-BDIZC
x-----x-

Copies the contents of the stack pointer into the X register.

Address Mode	Op-Code	Example	
Implied	BA	BA	TSX

TXA – Transfer X to Accumulator NV-BDIZC
x-----x-

Copies the contents of the X register into the accumulator.

Address Mode	Op-Code	Example	
Implied	8A	8A	TXA

TXS – Transfer X into Stack Pointer NV-BDIZC

Copies the contents of the X register to the stack pointer.

Address Mode	Op-Code	Example	
Implied	9A	9A	TXS

TYA – Transfer Y into Accumulator NV-BDIZC
x-----x-

Copies the contents of the Y register to the accumulator.

Address Mode	Op-Code	Example	
Implied	98	98	TYA

THE PROCESSOR STATUS WORD

All arithmetic, logic and load register instructions on the 6502 affect the flags. For example, the instruction **LDA** #$00 will set the zero flag and clear the negative flag (all other flags will be unaffected). Also, when performing a comparison (**CMP**, **CPX** or **CPY**), the processor effectively subtracts the value from the register specified. So, if the accumulator holds the value $05 and we use a **CMP** #$05, then the zero flag will be set (other flags will be affected, too). As well as indicating comparison and arithmetic results, some flags are used to specify the way in which the computer operates.

Carry (C)

The carry flag is normally used when adding or subtracting numbers which are larger than one byte long. When adding two numbers together, if the result is greater than 255, the carry flag is set. The *Add with Carry* (ADC) instruction automatically adds one to the result if the carry was set before the instruction was executed. This means that you need to place a *Clear Carry* (CLC) instruction before any addition.

```
0200 18       CLC        ;Compute 240 + 20...
0201 A9 F0    LDA #$F0   ;Load 240 into Acc.
0203 69 14    ADC #$14   ;Add 20
0205 00       BRK        ;Stop
```

When this program is run on the *Micro Lab*, the registers are automatically displayed afterwards, so you can see that the carry flag is set and the accumulator holds the value 04h. This makes the result of the addition 0104h (01h because the carry is set and 04h held in the accumulator). In decimal, this is 260.

Before subtracting a number from the accumulator, you should *Set the Carry*. This is because if the carry is clear before a subtraction, the computer automatically subtracts another one. After performing the subtraction, if the result is less than zero, the carry flag is cleared.

```
0200 38       SEC        ;Compute 010Fh – 0010h
0201 A9 0F    LDA #$0F   ;Load Acc. with 0Fh
0203 E9 10    SBC #$10   ;Subtract 10h
0205 AA       TAX        ;Store result in IX
0206 A9 01    LDA #$01   ;Load Acc with 01h
0209 E9 00    SBC #$00   ;Subtract 00h
020B 00       BRK        ;Stop
```

This program shows you how to subtract two numbers which are stored in more than one byte. Firstly, we subtract the lower bytes from each other, setting the carry flag beforehand. Next we subtract the high bytes from each other with the carry set or cleared by the previous subtraction. As the result of the first subtraction was less than zero, the carry is cleared and the result of the second subtraction becomes zero. The flag may also be used when comparing two numbers together.

Zero (Z)

The zero flag is set whenever the result of a calculation becomes zero. So, if the IX register holds the value $01, then after the instruction **DEX** the zero flag will be set. As shown above, the zero flag may also indicate that a comparison result was *equal*.

Interrupt Disable (I)

When set, this flag inhibits interrupts generated by changing the voltage on the IRQ pin from high to low.

Decimal (D)

When this flag is set, the addition and subtraction instructions operate in *Binary Coded Decimal* (BCD). When using BCD, four bits are used to hold values between 0 (0000) and 9 (1001), values above 9 are invalid. So, adding 01h to 09h would give 10h (not 0Ah).

Break (B)

When a BRK instruction is executed, the break flag is set and an IRQ interrupt generated (see the section on interrupts). Without the break flag, the interrupt routine would have no way of knowing whether it was called because a BRK instruction was executed or a genuine interrupt occurred.

Overflow (V)

When using a byte as a signed number (between -128 and +127) instead of an unsigned number (between 0 and 255) we need to know whether an arithmetic instruction has overflowed (gone above +127 or below -128). The overflow flag is set when this occurs.

Negative (N)

The negative flag is set when the result of the last operation was negative (bit 7 set). This flag may also be used when comparing two numbers.

routine. The address of the routine to be called is stored in the program EPROM (addresses FFFEh and FFFFh for the IRQ routine and addresses FFFAh and FFFBh for the NMI routine).

This routine is run until a *Return from Interrupt* (RTI) instruction is encountered. This instruction is similar to the RTS instruction except that it informs the CPU that the interrupt has been *serviced* and it also pulls the PSW flags from the stack in addition to the return address. The difference between the two interrupt pins (other than the interrupt address) is that the IRQ pin may be ignored by setting an *Interrupt Disable* flag (using the SEI instruction). The NMI pin will always generate an interrupt. On the *Micro Lab*, there are two devices which may cause interrupts. The first is the keyboard and the second is the 6522 VIA.

KEYBOARD INTERRUPT

Whenever a key is pressed, the keyboard controller i.c. informs the monitor program by generating an interrupt. The monitor stops what it is doing and jumps to a routine which reads the key code, converts it into an ASCII value and stores it in a buffer. When the monitor routine which reads the keyboard is called, it simply checks whether there are any key presses stored in the buffer and returns with the value of the first key pressed (if any).

An alternative way to read the keyboard would have been to ask the keyboard controller at regular intervals whether a key has been pressed – this is called *polling*. The disadvantage of this is that the program will miss any keys which have been pressed between polls.

Imagine that you are having a party and you are getting everything ready for it whilst waiting for the guests to arrive. If you have a doorbell or knocker then you will spend most of your time preparing the party and will answer the door whenever the bell rings (an interrupt has been generated). If you do not have a bell or knocker, then you will have to stop every few minutes to open the door to check whether there is anyone there. Some people may get bored of waiting and wander off if you don't check the door often enough!

6522 VIA INTERRUPTS

Interrupts generated by the 6522 are ignored by the monitor program – the interrupt routine simply exits with an RTI instruction. However, it is possible for you to intercept this interrupt for use in your own programs by changing the *interrupt vector* in RAM. This should only be attempted after you have had some experience programming the *Micro Lab*.

THE BREAK (BRK) INSTRUCTION

You will have noticed that most of the programs given so far end with a BRK instruction, which returns the computer to the monitor. This instruction works by setting the *Break Flag* in the PSW and then it generates an interrupt in the same way as the IRQ pin. The interrupt routine is then called automatically. The first thing this routine does is to check the break flag to see whether a genuine interrupt occurred or a BRK instruction was executed. If it was a BRK instruction, then the routine displays the registers and jumps to the monitor.

Next month sees the last part of the Teach-In series. In it we will look at more microprocessor operations. Practical experiments will include closed loop control of temperature, control of stepper motors, frequency generation, and making the *Micro Lab* play some music. After the Teach-In series comes to an end we will occasionally publish some exciting new projects that will use the *Micro Lab* as their "command and control" centre. Look out for *Robo Spot* – our computer controlled buggy!

CORRECTIONS TO TEACH-IN '93 PART 10

On page 586 last month part of the Op-Codes were published as "XX" we apologise for this. The correct examples are shown below.

Zero Paged Indexed example should read:

```
0200  A2 20   LDX  #20h    ;Load IX with 20h
0202  A5 F0   LDA  F0h,X   ;Load acc. with contents
                           ;of address 0010h
```

Indexed Indirect Addressing example should read:

```
0200  A2 06   LDX  #06h
0202  A1 90   LDA  (90h,X)
```

Indirect Indexed Addressing example should read:

```
0200  A0 04   LDY  #04h
0202  B1 90   LDA  (90h),Y
```

WORKING IT OUT

ROBERT HOLLINGS

Some simple guidelines on making approximate calculations, without becoming too "pi-eyed"

READERS who followed the series by Mike Tooley *Design Your Own Circuits* (*Teach-In '91* – Dec '90 to Sept '91. This series will be published in book form as Teach-In No6 in November this year – Ed.) should have gained some skill in making calculations at the same time. Even if you are not interested in designing, there have been plenty of other articles involving formulae, for example for testing and fault-finding on a constructed project.

These days it makes sense to use an electronic calculator for solving such problems, and it is not the intention of this article either to teach you mathematics or to tell you how to use a calculator. There are plenty of books on both topics, and in any case so much depends on which particular calculator you are using.

APPROXIMATION

What we do want to do is to explain the methods used to get an approximate answer without a calculator. There are two reasons for doing this.

1. At some time or other you might need to perform a calculation when a calculator is not available, or when it has a flat battery. In many cases in electronics, an approximate answer is good enough. For a resistor value, for example, an answer of 'between 50k and 60k' will usually tell you that you need only try 56k and 47k resistors, as opposed to 33k or any other 'preferred value'. For a voltage reading an answer of 'about 5 volts' is enough to tell you that a meter reading of 2 volts indicates a probable fault in that area of the circuit.

Bearing in mind that resistor short circuits are so rare that you can regard them as impossible, the nature of the fault is often obvious or can be determined with one or two additional measurements. You may just want to know which range to set on the meter, i.e. are you likely to be reading volts or millivolts? (O.K., so yours is an "autorange" meter, but some of us can't afford one!)

It can happen, in fault finding, that strictly calculating a "correct" value can throw you off the track. Say for example that the calculated voltage at a voltage divider junction is 4·56V, and your meter reads 3·9V. You might think that a fault is indicated, but it is more likely that one or both resistors are close to their tolerance limit. Alternatively, if the resistor values are large, your meter may be forming a parallel resistance to one of them, thus lowering the combined resistance and giving a reading which is lower than the voltage which occurs when you remove the meter!

2. It is always a good idea to get a rough answer before you use the calaculator to get a more exact answer. It is so easy to press the wrong buttons or to put the decimal point in the wrong place. If you have no idea what the correct answer should be, you will not know that you have made an error, whereas if a "rough estimate" is 50 and the calculator's answer is 437·456, you will know that at least one of them is wrong!

BE SENSIBLE

Basically, the method I use relies on making sensible approximations for each factor in the problem, so that you can cancel as far as possible, and thus simplify the expression. In most cases it should be possible to reduce the expression to one which involves only addition, subtraction, multiplication and division.

The idea is to reduce the number of terms you have to write down (or key into the calculator) in order to come up with the approximate solution. With experience, you will often find that you can cross out several terms straight away and complete the calculation mentally.

MAKING RULES

The rules for the method are fairly simple:

1. First look for powers of ten, and cancel out as many as possible of these, remembering the rules for dealing with indices. Remember that an index of ½ indicates a square root, whilst a negative power of ten means a value less than one. I will assume that readers know how to cancel out such terms but if you have any trouble with them, find a good library book and do all the exercises, as it is important to get these right.

It should be pointed out that this method of calculating does not remove the need to be extra careful with power of ten. We have all done it, of course, but if you spend half an hour with a 330 ohm resistor and a puzzled frown when you should be using a 33 kilohm resistor, you have only yourself to blame!

2. Round off any decimal numbers to the nearest whole number, unless retaining a decimal place will make cancellation easier. For example, if you have 1·5 at the top of a fraction and 45 underneath, it makes more sense to keep it as 1·5.

3. If the problem involves awkward bits like π and a square root sign, try to simplify those parts, depending on the remaining figures. π can sometimes be treated as three, but if you have another factor of three or a multiple of three on the same line then it may be simpler to say that 3π is 10. Alternatively, saying that π is 3·2 might make it easier to cancel with a figure like 8 or 16.

Remember that you can say that $\sqrt{600} = \sqrt{60} \times \sqrt{10}$, for example, but you cannot say that $\sqrt{600} = \sqrt{400} + \sqrt{200}$. It's a common mistake and it just doesn't work. (Try it if you don't believe me!)

With that in mind, however, most square root problems can be reduced to numbers that you can approximate easily. In this example, $\sqrt{60}$ is a bit less than 8 (because 7×7 is 49 while 8×8 is 64) and $\sqrt{10}$ is a bit more than 3, so $\sqrt{600}$ must be about 24. We know that 20×20 is 400 and 25×25 is 625, so the answer looks about right.

4. Round off what's left so that you can cross out as many numbers as possible. You have to learn by experience just how much to crop particular numbers under specific circumstances.

For a quick voltage check, for example, you might be justified in saying that 36 is nearly 40. For a resistor value, if you don't have the calaculator, it would probably be better to leave it as 36 even if it doesn't cancel with anything. Similarly for a frequency you might need to say that 2π is 6·28 or 6·3 perhaps, rather than rounding it off to 6.

5. Try not to make too many drastic cuts in the same direction, and bear in mind whether your approximation is greater or less than the true figure. For example $36 \times 2{\cdot}6$ is better approximated to $40 \times 2{\cdot}5 = 100$ rather than $40 \times 3 = 120$, since the true answer is about 94.

MAKING IT EASIER

Apart from that it's really just a matter of practice. Let's look at a fairly typical example. Suppose that putting figures into a formula gives you the following expression:

$$F = \frac{36.457 \times 15.347 \times 10^{-3} \times 23{\cdot}75 \times 10^2}{2\pi \times \sqrt{(7{\cdot}725 \times 10^{-3} \times 61{\cdot}457 \times 10^2)}}$$

Looks pretty awful, doesn't it? Since most calculators have a key for π and one for square roots, it is tempting to start pushing buttons straight away. But lets take a look at the figures first.

On the top line, we can easily get rid of both of the exponents by remembering that $10^{-3} \times 10^2$ gives 10^{-3+2} which is 10^{-1} and that is just 0·1. Now we can multiply that by 15 (ignoring the decimal places in the second term), which gives $(1{\cdot}5 \times 36{\cdot}457 \times 23{\cdot}75)$ for the top line. maybe we can cancel some of these figures with the lower line, so lets look at that next.

Well, for a start we can do the same thing with the figures in the brackets. This gives $[2\pi \times \sqrt{(7{\cdot}725 \times 6{\cdot}1457)}]$ for the lower line. We can approximate the square root to "nearly 8" times "a bit more than six", which when multiplied gives "about 48" to be square rooted.

Well, seven squared is 49. That's near enough, so we can write 7 here and remove the square root sign. We have therefore reduced the expression to:

$$F = \frac{1{\cdot}5 \times 36.457 \times 23{\cdot}75}{2\pi \times 7}$$

We can still make things a bit easier. Let's say that 23·75 is "nearly 24", so 1·5 × 23·75 is then "about 36". It is not quite as much as that, however, and with the figures we have it is actually more convenient to call it 35. We can then cancel out the 7 to give 5 on the top line. Similarly, 2π is "about 6", which cancels out with the 36·457 to give 6 and a bit.

Now we just have "six and a bit" times 5, i.e. something a bit bigger than 30. If you care to use the calculator on the original expression, you should find that the correct answer is 30·0236229358, to 10 places of decimals.

TRUE ANSWER

All right, I admit I cheated slightly. After picking some numbers out of thin air I altered a few of them to provide a better example. However, I promise you I did not know in advance that my "estimate" would end up that close to the correct answer!

Of course, not every answer will be as close as that, but a least we can now be fairly sure that this answer is correct. If the calculator had shown 0·3002 ... or 300·236 ... then we would know that something is wrong.

If you do have a calculator available, there is usually no harm in using it to get an answer from the simplified expression. In this particular case, we get an answer of 29·53, correct to two decimal places, and for a resistor value that is probably near enough to save you the bother of keying in the precise values.

It indicates that you should try a "high" 27 ohm resistor and a "low" 33 ohm one, and solder in whichever of the two gives the desired result. It certainly shows that there is no point in trying either 22 ohms or 39 ohms.

For a voltage reading, the answer indicates that you should set the meter to 50V f.s.d. (full scale deflection) if there is such a setting, or 100V if not, and that if the meter gives a reading somewhere between 25 and 35 then this part of the circuit is probably all right. That will of course depend on what kind of circuit is involved, since certain types of circuit will obviously have less tolerance than others.

Readers of this magazine are of course unlikely to deal with current readings of around 30 amps. However, if we pretend for the moment that the answer is say 30mA, then the same applies to a current reading. □

SHOP TALK

with David Barrington

Sound Activated Camera Trigger

The printed circuit board for the *Sound Activated Camera Trigger* has been designed to accept the specified relay and other types are not likely to fit on the p.c.b. directly. If an alternative relay must be used, although we recommend against it, you will probably have to mount it separately and "hard wire" it to the p.c.b.

As the camera or motor drive requirements may be "unknown", the relay chosen is rated at 12V d.c. and has contacts capable of handling 10A resistive loads and 3A for inductive loads. This should be more than enough for most camera requirements.

The relay used in the model is the **Maplin** "Ultra Miniature High Power Mains Relay," code YX97F. Note that it is the "normal open" (n.o.) contacts which are wired in circuit. The small printed circuit board is available from the *EPE PCB Service*, code 840.

Some further points which need to be considered when ordering parts are as follows: The electrolytic capacitors should be miniature radial p.c.b. mounting types and the polyester "caps" should have lead spacing of 7·5mm, these usually fall into the "poly layer" range.

The unit is designed for operation with a low (200 ohm to 600 ohm) impedance microphone, but it should work with practically any type. Audio quality is not paramount here and possibly a cheap "cassette" dynamic microphone would be a good choice.

The specified relay is designed to work down to 9V and, as mentioned in the article, a small saving could be made by opting to use six HP7 cells instead of eight. Bear in mind though, that 12V is needed to guarantee relay operation when the battery voltage falls due to ageing.

Finally, how the trigger unit is connected to the camera will, of course, vary to suit the camera used. On the model 4mm sockets were used as they matched the camera remote control lead.

If the control lead has a non-standard connector, at the controller end, this can be cut off and the lead soldered directly to the relevant p.c.b. pads.

Charge 15

There are one or two points to be aware of when tackling the *Charge 15* project, but most of the components should be generally available through our advertisers.

The first and most important point to make is: *"on no account attempt to charge standard (non-rechargeable) dry cells"*. Also, and equally important is that "mains voltages" are involved when constructing this unit and extreme care must be exercised at all times. Make sure that the unit is unplugged from the mains before carrying out any work on the charger.

The ratings specified for the mains transformer should be within the range of stocks held by advertisers. However, if local difficulties are encountered, transformer specialist **Jaytee Electronic Services** (☎ *0227 375254*) should be able to come up with an ideal version. Also, the **Marco** TFX/CT13 and **Maplin** WB25C are similar to the one used in the model.

The physical size of 24VA/25VA transformers does tend to vary with manufacturer, so it might be wise to check its size before ordering the metal case.

As a certain amount of heat is generated inside the metal case (a metal case *must* be used), it might be a good idea to select a larger size case than specified. In any event, make sure there is plenty of ventilation by adopting the method suggested and possibly drill some additional vent holes in the base.

The bead thermistors are of standard rating and should not pose any supply problems. The high wattage resistors used in the model are also widely stocked and are the wirewound types encased in a ceramic block. These resistors should be mounted slightly proud of the tagboard to allow cooling air to circulate around them.

The relay used in the prototype is the Iskra type TRK1703 and only appears to be available from Rapid Electronics. This company only supplies to the trade and educational establishments. However, the "high power mains relay" from Maplin appears to have exactly the same connecting pin layout and fitting.

This relay has a 320 ohm coil and contacts rated at 10A (resitive) which make it suitable for use as a direct replacement, without any modification. The order code for this relay is: YX97F.

There are numerous suitably rated relays on the market that meet the electrical criterion, but the layout of the connecting lugs all appear to differ from the one in the prototype. This applies particularly to the coil contacts.

There is no reason why other relays should not be used, it simply means altering the board foil layout to cater for the alternative relay coil contact arrangements. The switching contacts are wired directly, using 3A minimum mains wires, so present no problems here. Another alternative would be to mount the relay off-board and to solder leads from the coil contacts directly to the existing copper pads on the board.

Light Work

The only item that could possibly cause some concern to constructors of the *Light Work* project is the choice of warning buzzer. Some of the "low cost" buzzers may not be heard from the driving position, so it is recommended that one of the "power" piezoelectric transducers should be chosen.

It is important that it be of a type which does not require any external drive circuitry. The one used in the prototype is the **Maplin** "High Power Buzzer," code FK84F. However, most of our advertisers should be in a position to recommend a suitable transducer from their stocks.

The light dependent resistor seems to be rarely listed under its type number any more and may, in some cases, be found in some advertiser's catalogues under a heading entitled "Photoconductive Cell" in their Opto Devices section. However, if you just ask for an "ORP12" device most suppliers will understand what is required.

The small battery holder shown in the accompanying photographs of this project was purchased from **Maplin** and is a PP3 p.c.b. mounting type, code JK65V. It is not essential to use the specified holder, a standard PP3 holder and battery connector will suffice.

Amstrad PCW 8-Channel A/D Converter

We do not expect any buying problems to be encountered by readers who wish to build the simple *Buffer* and *Filter* circuits for use with the *Amstrad PCW 8-Channel A/D Converter* (described last month).

The Schottky diode type BAT85 only appears to be listed by **Electromail** (☎ *0536 204555*), code 300-978. When ordering the LF356N op.amp i.c., make sure you emphasise the letter ***N*** as this designates the 8-pin d.i.l. package version.

PLEASE TAKE NOTE

Innovations *(August 1993)*

In last month's news pages we carried a report on a special price reduction on Maplin's 15-Piece Students Tool Kit.

This information was supplied by Maplin and at £14.95 seemed a very worthwhile offer to bring to readers attention. However, they subsequently withdrew this promotion but forgot to notify the magazine.

Maplin wish to apologise for any inconvenience caused to readers for this oversight. The current price for the 15-Piece Students Tool Kit is £19.95, code BZ60Q. – Still good value for money.

Home Base

Jottings of an electronics hobbyist – Terry Pinnell

Life or Death in the Pantry?

Last month I described how I went about designing an electronic mousetrap for a friend who couldn't bring herself to use more conventional methods of rodent extermination. I'll conclude the saga with a description of the circuit as shown in Fig. 1

A d.p.d.t. on/off switch supplies 9V to the logic circuits and 18V for the solenoid. When the power is applied a positive-going pulse resets the bistable, ensuring that its output does not trigger the monostable.

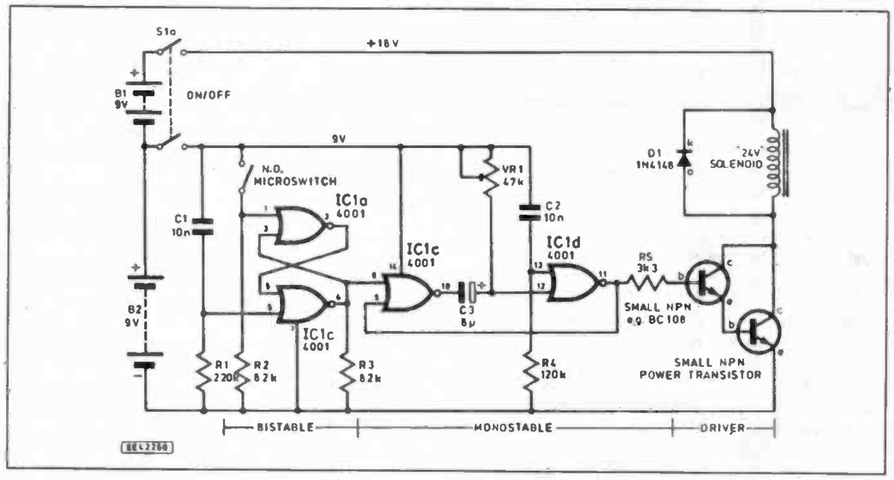


Fig. 1. Full circuit diagram of the Electronic Mousetrap.

When the microswitch is closed as a result of the mouse's weight, the bistable is set. This triggers the monostable, the output of which goes high for a brief period set by VR1 and C3. The preset VR1 allows adjustment to the shortest time consistent with reliable release of the trapdoor. In practice this proved to be about 0·3 seconds.

As a further precaution against spurious triggering on power-up, the monostable has a simple *RC* network on pin 13 to keep the output low for a short time.

The high monostable output drives a Darlington pair common emitter via R5, activating the solenoid. This pulls inward, allowing the trapdoor to drop sharply down. Diode D1 provides protection against possible induced high reverse voltages.

Power Supply

As I mentioned last month, I was surprised to find that my '24V' solenoids would work at all at only 18V, but naturally that was close to their threshold of reliable operation. I experimented for a while with voltage multiplier circuits, trying to get the necessary 18V minimum from a 9V or even 6V supply. However the surplus solenoid I was using was a current hungry specimen consuming some 600mA at 18V and such multipliers were not up to this sort of high load.

So I settled for two 9V batteries in series. I was initially doubtful whether the small PP3 types would be up to the job, and indeed trials with some slightly used ones gave unreliable operation. But fresh alkaline types worked consistently well; after all, they only had to deliver one good short burst per night.

Construction

Building the mousetrap was straightforward and should be clear from the figures and photograph. Any reader actually making one of these would naturally use materials to hand, adapting details as appropriate.

The platform I used to trigger the microswitch was a thin piece of wood, hinged very loosely to the base of the rectangular box by a couple of pieces of nylon fishing line. The microswitch arrangement is best arrived at by trial and error. The main thing is to ensure the switch is not triggered until your guest is well and truly inside the box, tail included.

A rear door was incorporated to assist in placing the cheese and cleaning out after the one night's unsolicited bed and breakfast.

The original version was given a Perspex top so that any inhabitant could be seen by the kind humans. However, on the first night of use captive mouse number one proceeded to eat its way out through this, securing escape. Incidentally, it must have been a very tiny mouse and had one heck of a squeeze getting out, because the hole it made was only about 1·5cm in diameter.

Anyway, I then replaced the Perspex with a thick wooden top and during the remainder of the week subsequent captives made no impact on this more robust version and were still inside the box in the morning.

Reinforced

Duly impressed with the toothpower of my prey I also reinforced the trapdoor and the rear door with an inner lining of thin aluminium. This caused a problem with the solenoid sticking because of the increased friction, but some sand-papering of the catch cured it.

Actually, thinking about this since, I wonder whether the aluminium reinforcement was redundant? The first mouse gnawed through the ceiling, even though that meant somehow hanging onto the side-walls while it did so, in preference to the more convenient and chewable original thin wooden trapdoors. Maybe that was because it could see through the Perspex and not the wood.

Presumably it didn't have enough sense to remember which was the way it had come in, and/or the constitution for it, so it tackled the material which it could actually see through, albeit dimly. Like the meaning of life and the vexed issue of where odd socks go to in the laundry, I suppose this question will for the moment have to remain one of the unanswered mysteries of the Universe.

Anyway, if I was making another mousetrap, I'd probably use aluminium entirely, shaping the box with four right-angle bends (including the edge for closing it with self-tapping screws). My only reservation would be whether the metallic appearance and feel could deter the mouse from entering.

The circuit, batteries and solenoid were housed in an improvised case. Two of my surplus 2oz tobacco tins (vestiges of pipe-smoking days many years ago) were bolted together back to back, and positioned to line up properly with the bevelled catch on the trapdoor. Of course, any appropriate sized case would do; aesthetics is not a factor in a nocturnal electronic mouse-trap.

Happy Ending

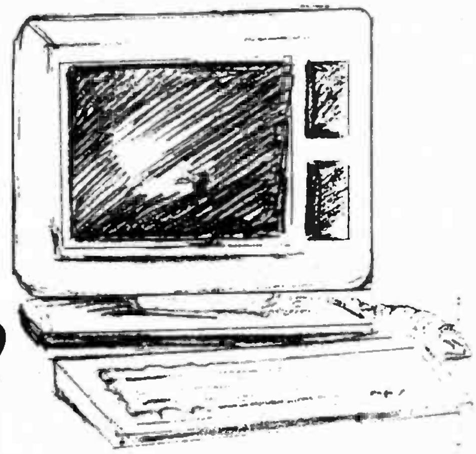
In use, the trapdoor was raised so that the solenoid plunger held it up by the bevel, and the toggle switch was then set to the "On" position.

Within the first week I was delighted to learn that it caught six mice, excluding the escapee. My friend assured me that they were transported about half a mile away before release. Scaling up to human levels I reckoned that must be about 10 miles, so I was reasonably sure it wasn't the same one coming back repeatedly.

Anyway, the word must have spread because the pantry was free of mice from then on. And everyone lived happily ever after!

The finished Electronic Mousetrap with the Perspex "edible" top replaced with chipboard.

AMSTRAD PCW 8-CHANNEL A/D CONVERTER



JASON SHARPE PART TWO

Using the ADC for monitoring/data logging and signal sampling. Plus construction of buffer/filter and pre-amplifier boards.

FOLLOWING on from last month's constructional project, this month we set out some further programming information and outline some possible applications for the Amstrad PCW 8-Channel A/D Converter. Included are a simple add-on Buffer Board, an Active Filter Board and a Pre-amplifier Board.

There are many uses for this analogue to digital converter unit. The first part of this article describes how to use the ADC for monitoring/data logging with simple "sensors". The second half describes its use for sampling signals at higher sampling rates and some elementary signal processing.

SENSORS

Some very simple sensors which can be connected to the 8-Channel ADC are shown in Fig. 1. Potentiometers can easily be connected to the ADC inputs and these can be used as input devices i.e. hand controls. For instance, analogue joysticks, which consist of two potentiometers (X and Y), can be connected to two channels and could for example be used to control a cursor. Or the potentiometer maybe connected to a stepper motor shaft or other device, to provide position information.

The light sensor, Fig. 1b, could be used to monitor light levels during the day. If a temperature sensor was connected the temperatures during the day could be logged.

Alternatively, the ADC could be used to replace a voltmeter on an existing project, as long as the voltage range is between 0V and 5V.

SIMPLE DATA LOGGER PROGRAM

A data logger program which reads all *Eight* channels at set intervals (set by the user) is set out in Listing. 1. The period

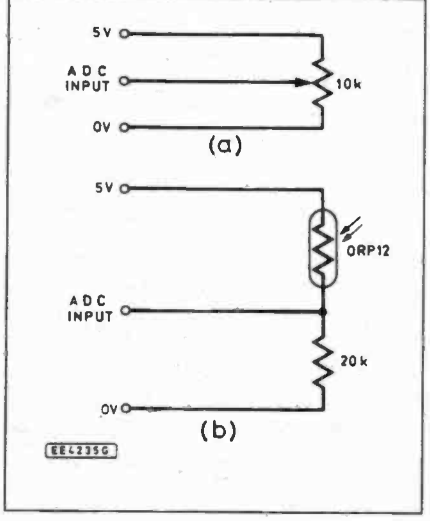


Fig. 1a. Connecting a potentiometer to the ADC. Analogue joysticks can be fitted, they consist of two 'pots' (for X and Y movement), and thus require two channels. (b) Light-level sensor. With a 20k resistor and an ORP12, the output voltage is nearly full range–from 0V to 5V

Listing 1. ADC Data Logger.

```
1 REM ************************************************************
2 REM *                 8-CHANNEL DATA LOGGER PROGRAM            *
3 REM *                   By  J.M.Sharpe (C) 1992                *
4 REM ************************************************************
5 :
100 ma=&HFBF7:sa=ma+1:REM                    Address of internal clock
110 OPTION BASE 0:DIM d(7):V=5/255:c$=CHR$(27)+"H"+CHR$(27)+"E":
120 PRINT c$"8-Channel Data Logger Program"
125 PRINT "-----------------------------":PRINT
130 PRINT "TIME BETWEEN READINGS (Minutes[59 max],Seconds[59 max])";
135 INPUT "",M%,S%
140 m%=ABS(m%):s%=ABS(s%)
150 IF m%>59 OR s%>59 THEN PRINT "INVALID DELAY !":GOTO 130
160 PRINT c$:PRINT "PRESS ANY KEY TO EXIT PROGRAM"
165 REM ****************Wait for end of time delay****************
170 PRINT:POKE ma,0:POKE sa,0
180 cm=VAL(HEX$(PEEK(ma))):cs=VAL(HEX$(PEEK(sa)))
190 IF INKEY$<>"" THEN END
200 IF cm<>m% THEN 180 ELSE IF cs<>s% THEN 180
205 REM ***********Read port values into array d(0..7)*************
210 d(0)=INP(176):REM                  Start conversion on channel 0
220 FOR Chan=1 TO 7:d(Chan-1)=INP(176+Chan)*V:NEXT: d(7)=INP(183)*V
225 REM **********************Print results************************
230 PRINT "Channel   Voltage"
240 FOR Chan=0 TO 7
250 PRINT TAB(3);Chan;TAB(11);LEFT$(STR$(d(Chan))+".000",6)
260 NEXT: GOTO 170
```

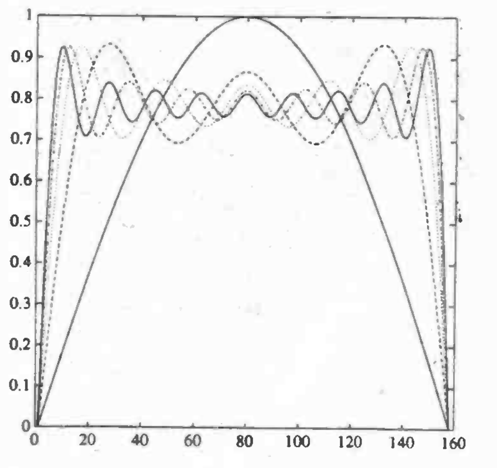


Fig. 2. The building of a square wave: Peaks at the edge are called "Gibbs' effect".

between readings is timed by using the internal clock. At present the data is simply displayed on the screen, but this could be changed so that the data can be stored in an array, or maybe dumped to the printer or a file, depending on the amount of information you wish to store.

The value read from the ADC will be between 0 and 255, this can be converted into the value of the input voltage by multiplying the value by (5 ÷ 255).

SAMPLING HIGHER FREQUENCY SIGNALS

To sample continuously changing signals (such as audio signals) ADCs are often used. This may be done for storage (e.g. converting sound to digital data for storage on CD or DAT), signal processing or signal analysis.

This all seems very straight forward, just keep reading in samples and store them in memory and process them as required. Unfortunately it is not quite this simple!

This is a very large and complicated subject, what follows is just a brief introduction. In 1807 Fourier presented his theory to the French Academy in Paris. Basically Fouriers' theory stated that an "arbitrary" single-valued real function (or signal) *can be represented by an infinite series of pure sine and cosine functions* (subject to certain conditions).

An example of this is shown in Fig. 2, a square wave can be built up of odd harmonics of sine waves, as the number of sine terms used increases the more the signal looks like a square wave. Large "peaks" start to build up at the edge of the square wave, this is called "Gibbs effect", but we shall not worry about this.

You can examine the "frequency components" (the frequencies of the sinusoidal components which make up the signal) of signals using a Spectrum Analyser – if you are lucky enough to have access to one of these, as they are rather expensive.

So what has this got to do with ADC's? Well they take samples of signals at discrete moments in time. Fig. 3 shows what happens to a signal which is sampled too slowly, the signal reconstructed from the sampled data is a lower frequency than the original signal. This is called "aliasing".

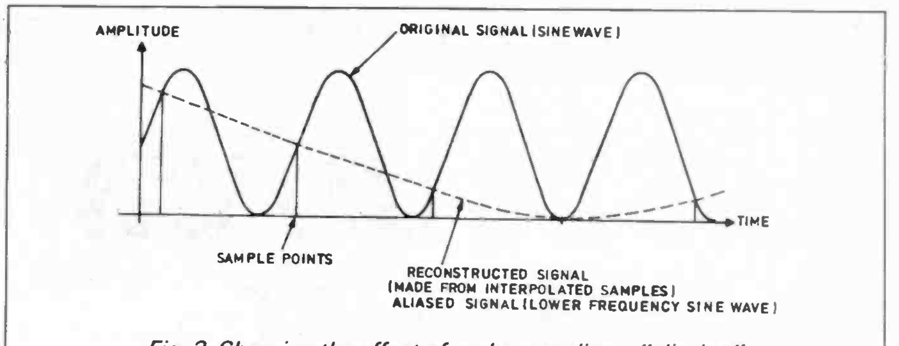


Fig. 3. Showing the effect of under sampling – "aliasing".

All frequency components of the signal which are greater than twice the sampling frequency are "aliased" to lower frequencies, which causes the sampled signal to be distorted (once this has happened there is no way of getting back the original signal). To prevent aliasing the sampling frequency should be more than twice that of the highest frequency component of the signal being sampled (this is called Nyquists' Theorem).

A low-pass filter is normally used to remove the high frequency components of the input signal. Sampling at half the highest frequency requires a perfect low-pass filter (which do not exist!), so in practice higher sampling rates are normally used.

BUFFER/FILTER

The circuit diagram of a buffer and 4th order low-pass filter is shown in Fig. 4. The buffer is there to provide a high input impedance, and also to shift the "bias" on the input signal if required. The filter cutoff frequency is about 16kHz.

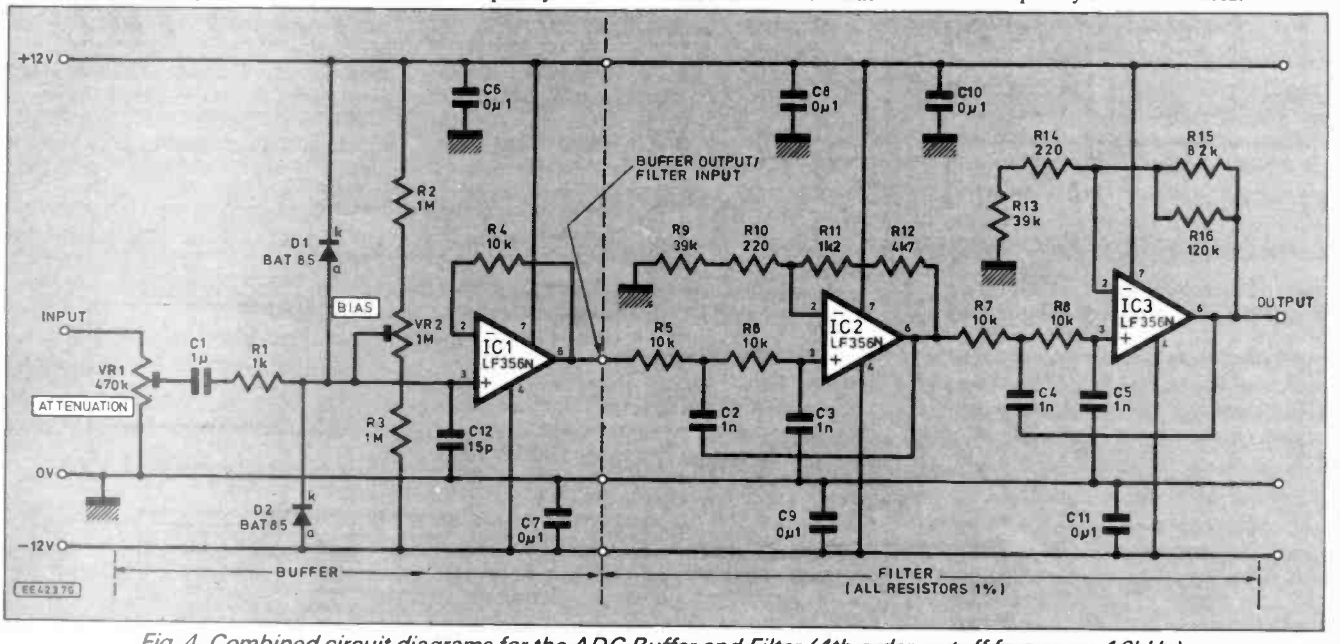
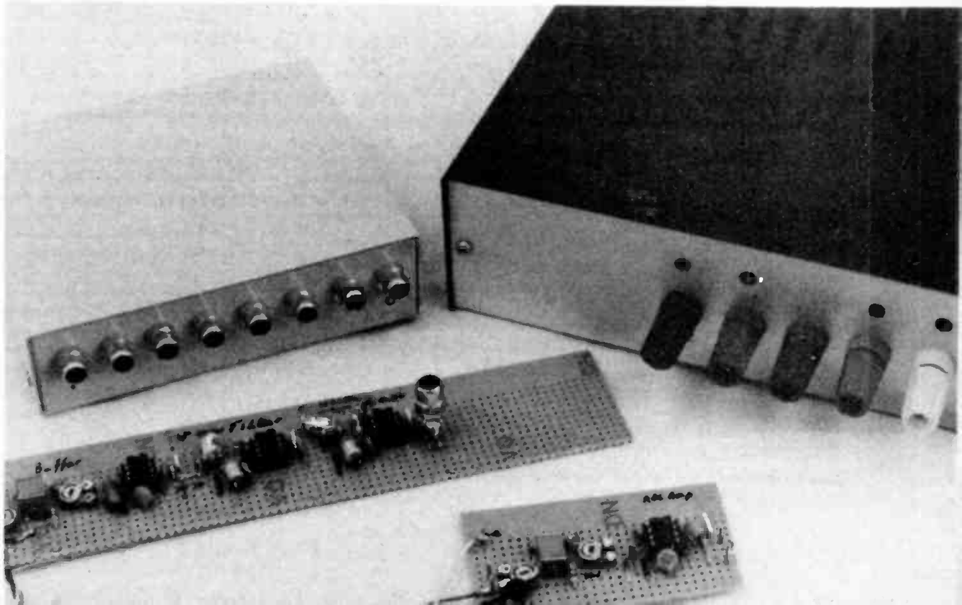


Fig. 4. Combined circuit diagrams for the ADC Buffer and Filter (4th order, cutoff frequency 16kHz).

Buffer

The gain of the Buffer is one, i.e. the output signal is of the same amplitude as the input signal. Preset potentiometer VR1 can be used to attenuate the input signal if it is larger than required. The filter unit has a gain of 2·6 (8·3dB), so if using the buffer with the filter VR1 should be adjusted so

Completed ADC, Linear Power Supply, Buffer/Filter board and Pre-amplifier board (foreground).



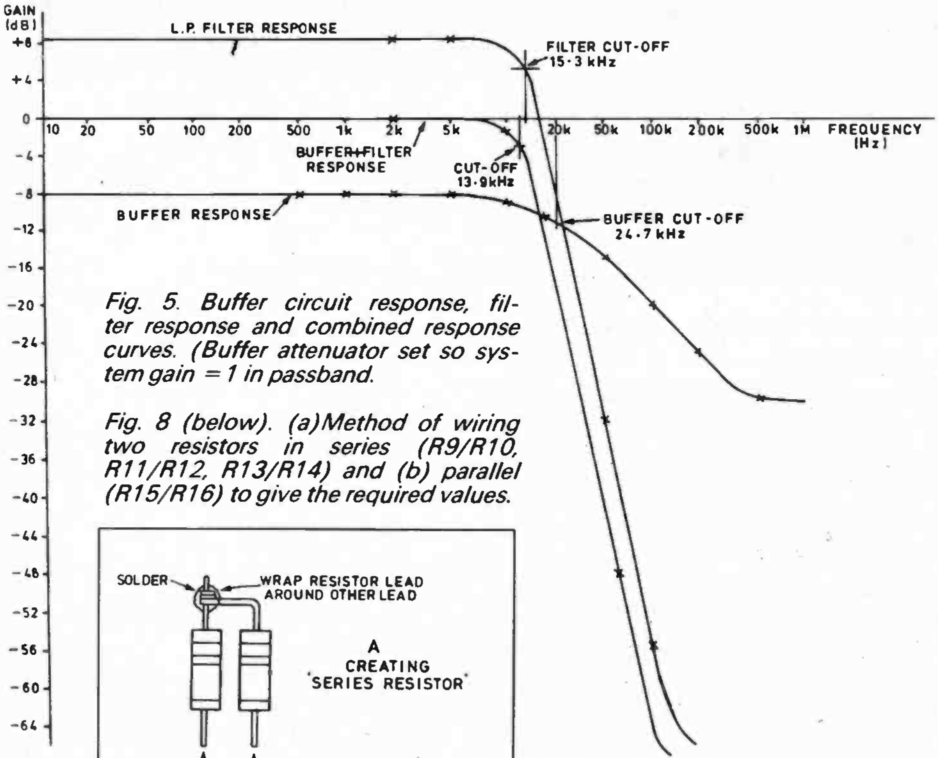
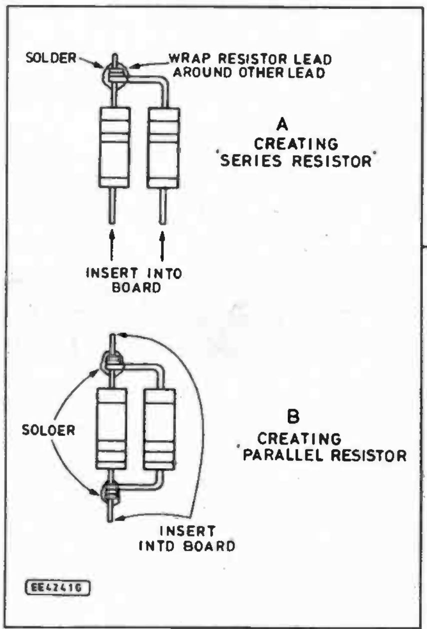


Fig. 5. Buffer circuit response, filter response and combined response curves. (Buffer attenuator set so system gain = 1 in passband.

Fig. 8 (below). (a)Method of wiring two resistors in series (R9/R10, R11/R12, R13/R14) and (b) parallel (R15/R16) to give the required values.



the combined filter and buffer has a gain of one.

Capacitor C1 removes any d.c. bias from the signal. The voltage from the slider of preset VR2 is added onto the signal. This is useful if, for example, the input signal is a sinewave which is oscillating between ±2·5V. If the buffer output is set to 2·5V (with no input signal), then when the input signal is applied, the output would be a sine wave oscillating between 0V and 5V (which can be inputted into the ADC).

Capacitor C12 filters off high frequencies. The diodes D1 and D2 are to protect the input from voltages outside the supply rails (±12V). Note that because of C1 this buffer will start to attenuate signals below ≃10Hz.

Filter

The Filter is an active 4th order low-pass Butterworth filter made of two cascaded 2nd order low-pass filters. The cutoff frequency of the amplifier (when the gain has fallen to 0·707 of the original value) is around 16kHz. The exact cutoff frequency will depend on the tolerance of the components used.

The actual cutoff frequency of the prototype was 15·3kHz which is within 5 per cent of the expected value. The frequency response of the prototype buffer, filter and their combined response is shown in Fig. 5.

With a fourth order filter the gain starts to fall at 24dB/octave (i.e. the gain is reduced to 0·0631 of its last value every time the frequency doubles) after the cutoff frequency.

One "unit" of voltage to the ADC is (5 volts/255) ≃ 20mV, so an input voltage of 1mV or 10mV would still give the value of 0. The highest sampling rate possible on the PCW is 200kHz, this means that all frequencies above 100kHz (Nyquist) should be reduced to a negligible value, i.e. below 20mV.

If a 100kHz sine wave with an amplitude of five volts is introduced to the input, it would have to be reduced to 0·004 of its original value to be negligible. A fourth order filter with a cutoff frequency of 16kHz achieves this as its gain has fallen to less than 0·001 by 100kHz.

CONSTRUCTION

The Buffer and Filter circuits can be easily constructed on stripboard. The Buffer component layout and breaks required in the underside copper tracks is shown in Fig. 6 and board details for the Filter in Fig. 7.

The component leads, jumpers etc. should be kept as short as possible to help prevent "stray" pickup. Some of the

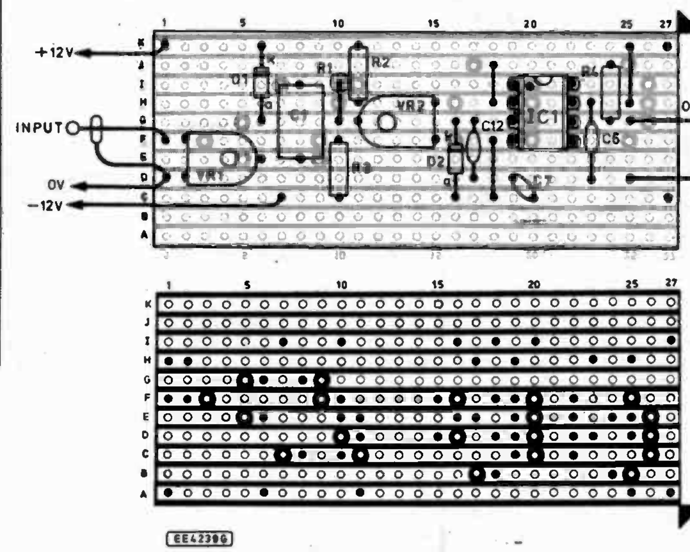


Fig. 6. Stripboard component layout and details of breaks required in the underside copper tracks of the Buffer board.

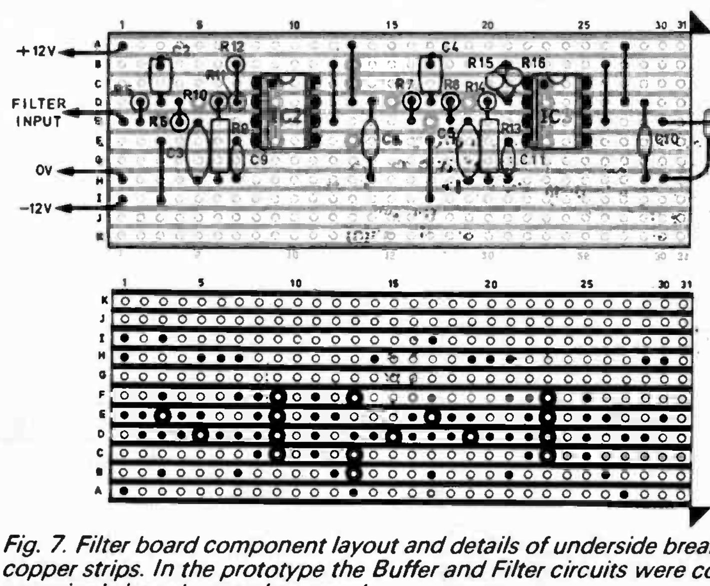
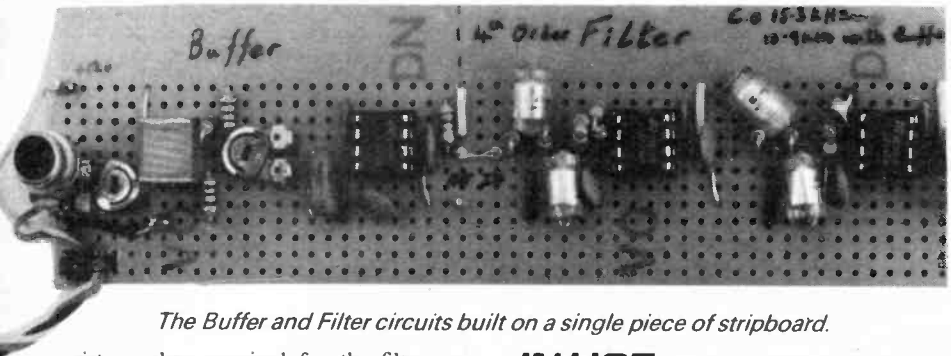


Fig. 7. Filter board component layout and details of underside breaks in the copper strips. In the prototype the Buffer and Filter circuits were combined on a single board – see photograph.



The Buffer and Filter circuits built on a single piece of stripboard.

resistor values required for the filter are non standard and so are made of series/parallel combinations, Fig. 8 shows how these can be made up to fit the layout.

SETTING UP

To set the gain of the whole system to "one", attach a 1kHz sinewave generator to the input of the buffer (connect the buffer output to the filter input if you have not already done so) and the filter output to an oscillloscope. Adjust VR1 until the input and output signals are the same size.

If you do not have access to an oscilloscope, set the d.c. output voltage to 0V by adjusting VR2, and use a 100Hz signal and an a.c. voltmeter. Adjust VR1 until the input and output voltages are equal.

The most useful value to set the bias to is probably 2·5V. To do this adjust preset VR2 until the (d.c.) output voltage of the unit is 2·5V, with the input unconnected.

IN USE

The Filter and Buffer Unit was designed for sampling audio signals, although it can be used for other purposes. The buffer input can be connected directly to the "Ear" or "Ext.Spk." output of most cassette players.

Set the bias to 2·5V as described above, if you have a 'scope connect it to the filter output and adjust the volume on the cassette player so that the output always remains within 0V to 5V. When this is done connect the output to the ADC. Otherwise start with the volume at minimum, and use the program described later, increasing the volume until it is at a reasonable level.

PRE-AMPLIFIER

If you wish to digitise smaller signals Fig. 9 shows a circuit diagram for a Single I.C. Pre-amplifier. The purpose of potentiometers VR1 and VR2 are the same as in

COMPONENTS

PRE-AMPLIFIER

Resistors

R1	1k
R2, R3	1M (2 off)
R4	10k
R5	47k

All 0·25W 5% carbon film

Potentiometer

VR1, VR2	470k enclosed carbon preset, lin. (2 off)

Capacitors

C1	1µ polyester layer
C2, C3	0µ1 ceramic (2 off)
C4	22p polystyrene

Semiconductors

D1, D2	BAT85 Schottky diode (2 off)
IC1	LF356N f.e.t.-input wideband op.amp

Miscellaneous

Stripboard 0·1in. matrix, size 10 strips x 30 holes; case to choice (optional); 8-pin d.i.l. socket; conectors; multistrand connecting wire; solder pins; solder, etc.

Approx cost guidance only **£5**

COMPONENTS

BUFFER/FILTER

Resistors

R1	1k
R2, R3	1M (2 off)
R4 to R8	10k (5 off)
R9, R13	39k (2 off)
R10, R14	220 (2 off)
R11	1k2
R12	4k7
R15	82k
R16	120k

All 0·6W 1% metal film

See SHOP TALK Page

Potentiometer

VR1	470k min. enclosed carbon preset, lin.
VR2	1M min. enclosed carbon preset, lin.

Capacitors

C1	1µ polyester layer
C2 to C5	1n polystyrene (±5% or better – 4 off)
C6 to C11	0µ1 ceramic (6 off)
C12	15p polystyrene

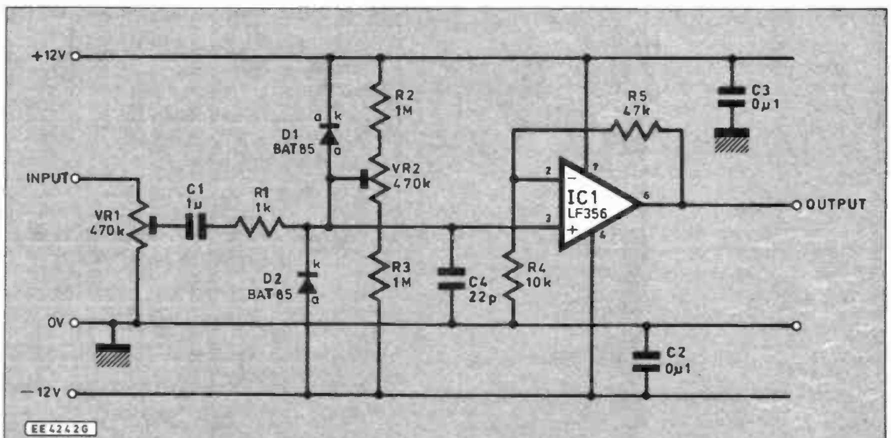
Semiconductors

D1, D2	BAT85 Schottky diode (2 off)
IC1, IC2, IC3	LF356N f.e.t.-input wideband op.amp (3 off)

Miscellaneous

Stripboard 0·1in. matrix, size 11 strips x 27 holes, and 11 strips x 31 holes; case to choice (optional); conectors; multistrand connecting wire; 8-pin d.i.l. socket (3 off); solder pins; solder, etc.

Approx cost guidance only **£8**



Circuit diagram for a simple Single I.C. Pre-amplifier (non-inverting).

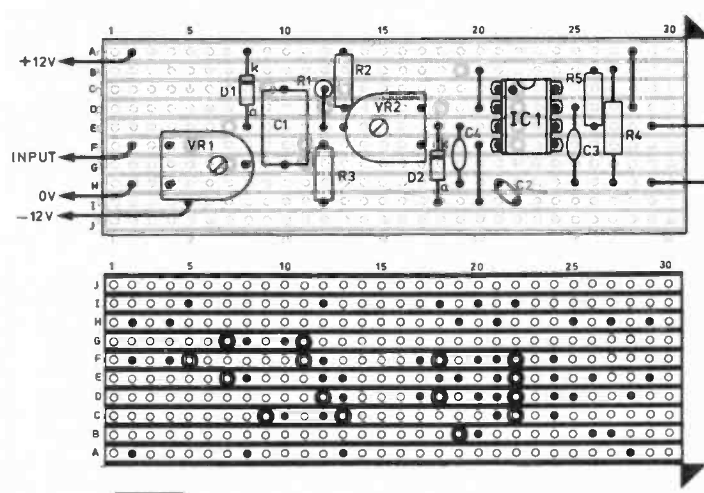


Fig. 10. Pre-Amplifier stripboard component layout and details of breaks required in the underside copper tracks.

the buffer circuit. The amplifier has a maximum gain of six. This circuit *cannot* be used to amplify d.c. signals due to capacitor C1.

The stripboard component layout is shown in Fig. 10. The construction details are the same as for the buffer.

DIGITAL SIGNAL PROCESSING

Volumes can be (and have been) written on the subject of digital signal processing so this is a very brief introduction.

Signals are digitised by taking discrete samples of a continous signal. Let the value of the first sample be (taken at time 0) x[0], the second taken at time T (the sampling period) be, x[1], ... at time nT be, x[n].

You now have an "array" of sampled values. These values can be processed in various ways. These digitised signals can be low, high, band pass (etc) filtered by using software routines. These processed signals can then be outputted to a DAC.

Software filters are often used as they are far more versatile than analogue filters. There are three basic building blocks that are used to make up software filters, these are shown in Fig. 11.

The time delay block delays a signal by 1 unit of time, if x[n] is input at time 1 then at time 2 the output will be x[n]. When inputting the array of sampled values the output is x[n – 1] when the input is x[n]. The multplier and summation blocks multiply or sum the inputs and output the result.

The PCW is not really fast enough for signal processing, as this is normally required to be done in "real time". But we have included a simple low-pass filter routine in the 'scope program described below.

The basic principle is shown in Fig. 12a. A sample, x[n], is feed into the filter, this is then added to the last value input into the filter, x[n – 1]. The result is then multiplied by 0·5 (output = 0·5 × (x[n] + x[n – 1])).

The output is the average value of the current sample and the last sample. This is called a two term moving averager and has a low-pass filter effect. Fig. 12b shows the effect it has on a signal, note that the amplitued of the "spike" is reduced more than the rest of the low frequency signal.

The filter implimented in the 'scope program uses four terms instead of two, as this has a more noticable effect. Fig. 13 shows a setup you can use to test the effect of the filter on sinewaves of different frequencies.

SCOPE PROGRAM

A simple Storage 'Scope program is shown in Listing. 2 and Fig. 14 shows some screen dumps from the program. The grid drawn on the screen is 500 ± 4µS per division horizontally and 1V per division vertically. Most of the program is written in machine code for speed. Some of these machine code routines can be called from basic.

Init: Sets up the screen. Must be called before other routines are used.

Scope: This is the main routine. When invoked a grid is drawn on the screen, it then takes 720 samples (one every 6µS) from the ADC and plots them on the screen. By default it does this 20 times, erasing the old line each time, and then returns to basic.

The number of scans can be altered by POKEing 'NoScans' with a value from 1 to 255 (0 will result in 256 scans). This routine calls the "Sample" routine to read in the data – see below.

Sample: Reads 720 samples (6µS period) from channel 0 of the ADC. The data can be accessed by PEEKing locations 'ADC data' to 'ADCdata' + 719.

Display1: This does the same as Display2 but erases the last plot displayed.

Display2: Plots the data stored by 'Sample' on the screen.

Grid: Plots a grid on the screen.

Hline(x1%,x2%,y%): High speed horizontal line drawing routine.

Vline(x%,y1%,y2%): High speed vertical line drawing routine. The X coordinates are in the range 0..719, and Y coordinates in the range 0..255.

MACHINE CODE PROGRAMS

To get the best performance from the ADC machine code subroutines can be written to be called from basic, or a stand alone program could be written.

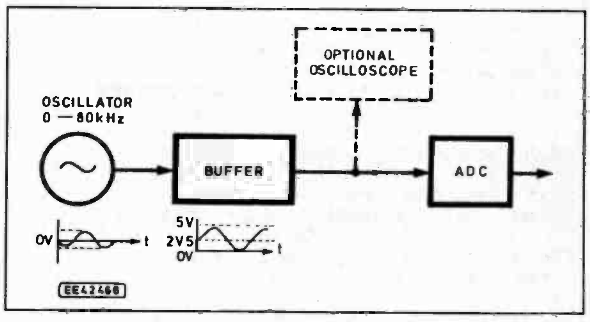


Fig. 13 (above right). Testing the effect of the software low bass filter.

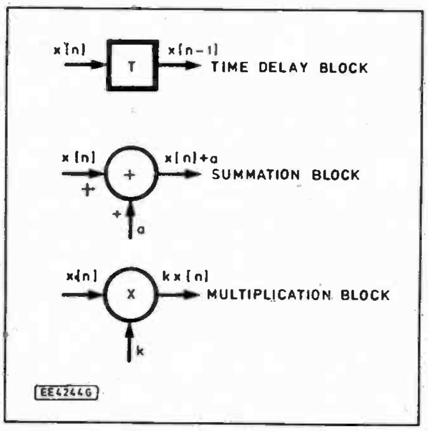


Fig. 11 (left). The three basic building blocks that are used to make up software filters.

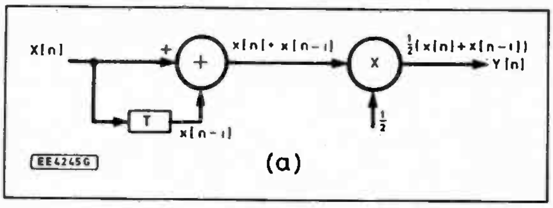
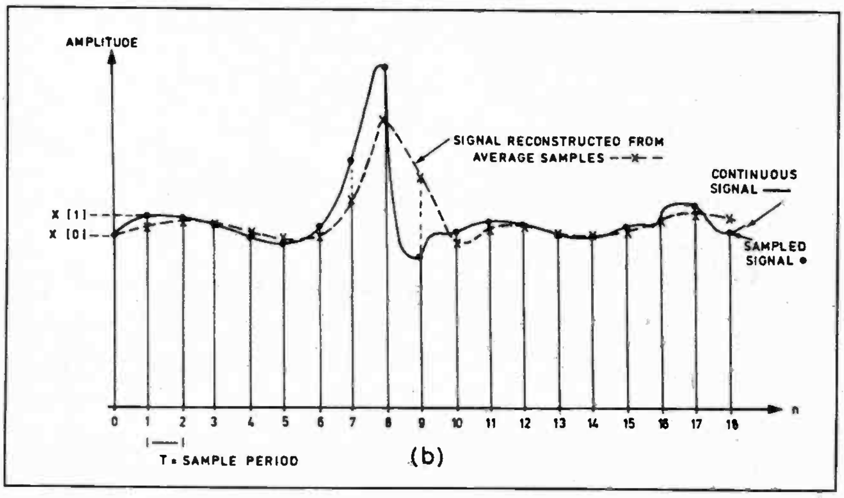
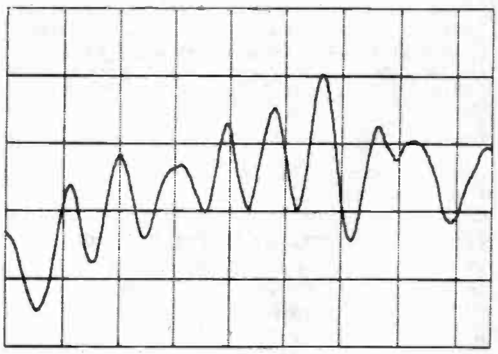


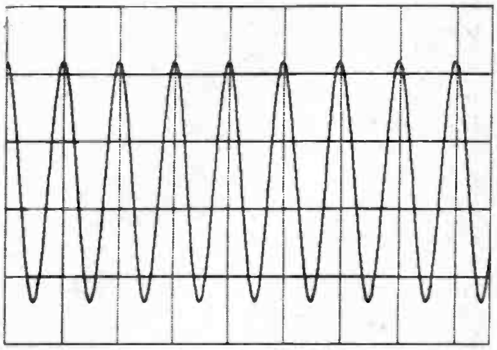
Fig. 12a (left). Simple low pass filter (two term moving averager).

Fig. 12b (below). Graph showing effect of two term moving averager.





(a)



(b)

Fig. 14. Sample screen displays using the 'Scope program (0·5mS division "horizontal" and 1·0V division "vertical").
(a) screen dump from some sampled music.
(b) screen dump of sampled 2kHz sinewave.

Listing 2: Storage 'Scope Program

```
1 REM ***************************************************************
2 REM *      Fast 'Scope' Program for use with 8 channel ADC        *
3 REM *                   By J.M.Sharpe  (C) 1992                   *
4 REM ***************************************************************
5 :
10 MEMORY &HCFFF :CLEAR:GOSUB 40000
99  REM *************************PROGRAM*****************************
100 CALL Init :REM                                 Initialise screen
110 POKE NoScans,5 :CALL Scope :REM                       Do 5 scans
120 FOR n=ADCdata TO ADCdata+720 :REM           Low Pass Filter data
130  POKE n,(PEEK(n)+PEEK(n+1)+PEEK(n+2)+PEEK(n+3))/4
140 NEXT n
150 PRINT "Press a key to plot filtered signal";
160 WHILE INKEY$="":WEND :CALL Display1:REM       Plot filtered value
170 PRINT CHR$(27)"HPress a key to continue                 "
180 WHILE INKEY$="":WEND :CALL INIT :REM        Re-Initialise screen
210 CALL Grid      :REM                                    Draw Grid
220 CALL Sample    :REM                                 Take samples
230 CALL display2 :REM                                       Display
240 REM                        Loop forever, Sampling when key pressed
250 CALL sample:CALL display1:WHILE INKEY$="":WEND:GOTO 240
39997 :
39998 END
39999 REM ************************SET UP MCODE************************
40000 ad=&HE000    :NoScans=&HE017 :ADCdata=&HE4D8
40010 Scope=&HE000 :Grid=&HE061    :Init=&HE053      :Sample=&HE06A
40020 Hline=&HE0A0 :Vline=&HE08F   :Display1=&HE070 :Display2=&HE079
40025 PRINT CHR$(27)"E"CHR$(27)"HSETTING UP";
40030 FOR n=1 TO 75:PRINT "*";
40040 READ c$,s:ck=0
40050 FOR x=1 TO 32 STEP 2
40060 c=VAL("&H"+MID$(c$,x,2)):POKE ad,c:ck=ck+c:ad=ad+1
40070 NEXT x:IF ck<>s THEN PRINT"ERROR IN DATA - LINE:";n:STOP
40080 NEXT n
40090 RETURN
40200 DATA "CD25E0CD5AE4CDB4E021DAE711DBE701",2548
40210 DATA "00033600EDB00614C5CD04E1CD14E1C1",1770
40220 DATA "10F6C340E0F3DD223EE0DDE1FDE5ED73",2809
40230 DATA "2FEB312DEB3E81D3F13CD3F2DDE90000",2221
40240 DATA "ED7B2FEBDD2A3EE03E85D3F13CD3F2FD",2604
40250 DATA "E1FBC9CD5AFCC200CD25E0CD5AE4C340",2666
40260 DATA "E0CD25E0CDB4E0C340E0F3CD04E1FBC9",2911
40270 DATA "CD25E0CD14E1C340E0CD25E021DAE711",2364
40280 DATA "DBE70100033600EDB0CD14E1C340E00A",1864
40290 DATA "471A4F7E23666FCD25E0CDB7E1C340E0",2112
40300 DATA "0A4F7E23666FEB7E23666FCD25E0CD7A",1865
40310 DATA "E3C340E03EAA0601CDE5E23EAA0601CD",2053
40320 DATA "1BE40E000606C521000011CF02CD7AE3",1291
40330 DATA "C13E33814F10EF210000060AFD21A5E1",1494
40340 DATA "C506FF0E00CDB7E1FD6E00FD6601FD23",2092
40350 DATA "FD23C110EB3EFF0600CDE5E23EFF0600",2038
40360 DATA "CD1BE4C90EB006D221D7E4EDB200EDB2",2373
40370 DATA "00EDB2C9FD21D8E4DD21DAE721000006",2088
40380 DATA "00C5DDE5E5DD4E00DD4601CDB7E1E1E5",2534
40390 DATA "FD4E00FD4601CDB7E1E1DDE1C1FD7E00",2511
40400 DATA "DD7700DD2323FD2310D7C5DDE5E5DD4E",2325
40410 DATA "00DD4601CDB7E1E1E5FD4E00FD4601CD",2219
40420 DATA "B7E1E1DDE1C1FD7E00DD7700DD2323FD",2535
40430 DATA "2310D706CFC5DDE5E5DD4E00DD4601CD",2151
40440 DATA "B7E1E1E5FD4E00FD4601CDB7E1E1DDE1",2801
40450 DATA "C1FD7E00DD7700DD2323FD2310D7FD7E",2101
40460 DATA "00DD7700C95300A700FA004D01A101F4",1525
40470 DATA "0147029B02CF023EFF90473EFF91B8D2",1828
40480 DATA "C5E14F7841903C575DCB3CCB1DCB3CCB",2031
40490 DATA "1DCB3CCB1D653E07A0CB38CB38CB3868",1735
40500 DATA "E5CD42E406004F09E5697982DAF8E1B9",2283
40510 DATA "CAF8E1FE09DA9FE23E07A33C47AF6737",2237
40520 DATA "1F10FD5F7AD608855729290115E209E3",1525
40530 DATA "DDE17BDDE9AE77237BAE77237BAE7723",2253
40540 DATA "7BAE77237BAE77237BAE77237BAE7723",1804
40550 DATA "7BAE773E0742A257CB38CB38CB38CA69",1884
40560 DATA "E2E12CE5CD42E47BAE77237BAE77237B",2248
40570 DATA "AE77237BAE77237BAE77237BAE77237B",1804
40580 DATA "AE77237BAE777B10D8E12CCD42E41415",1908
40590 DATA "C87BAE7715C8237BAE7715C8237BAE77",1960
40600 DATA "15C8237BAE7715C8237BAE7715C8237B",1723
40610 DATA "AE7715C8237BAE7715C8237BAE77C93E",1900
40620 DATA "07A33C47AF67371F10FD5F29092901B8",1305
40630 DATA "E209E3DDE1C1DDE9AE7715C8237BAE77",2520
40640 DATA "15C8237BAE7715C8237BAE7715C8237B",1723
40650 DATA "AE7715C8237BAE7715C8237BAE7715C8",1858
40660 DATA "237BAE77C9DDE5FDE5D9E5D5D9C54F21",2769
40670 DATA "79E37EA9714F06082149E2DD2116E2FD",1936
40680 DATA "2173E2110400D911060021B9E2D9CB21",1532
40690 DATA "D22DE33E77AE773E77DDAE00DD77003E",1934
40700 DATA "77FDAE00FD7700D93E77AE77D919DD19",2097
40710 DATA "D919FD19D910D7C13EAE0520043EB618",1706
40720 DATA "050520023EA606082148E2DD2115E2FD",1371
40730 DATA "2172E2110400D911060021B8E2D977DD",1634
40740 DATA "7700FD7700D97719FD19D919DD1910EE",1872
40750 DATA "D9D1E1D9FDE1DDE1C9FF3EFF914FE5AF",3193
40760 DATA "ED52E1F287E3EBAFED5223EBE5CB3CCB",2842
40770 DATA "1DCB3CCB1DCB3CCB1D653E07A1CB39CB",1813
40780 DATA "39CB3969CD42E406004F09C13E07A1F5",1683
40790 DATA "1514C2BEE383DABEE3FE08DA07E4F1CA",2576
40800 DATA "DBE3474F3EFFCB3F10FCE6FFAE77EB3E",2522
40810 DATA "08914FAF47ED42EB0E08094B43CB3ACB",1653
40820 DATA "18CB3ACB18CB3ACB180504CAF8E31108",1711
40830 DATA "003EFFAE771910F93E07A1C847AF371F",1662
40840 DATA "10FCE6FFAE77C943371F10FCC10504CA",2072
40850 DATA "16E4CB3F10FCE6FFAE77C932CBE332F2",2535
40860 DATA "E33203E43217E43EAE0520043EB61805",1359
40870 DATA "0520023EA632CCE332F3E33204E43218",1624
40880 DATA "E4C9F5D5E52600291195E4195E2356E1",2054
40890 DATA "6C26002929291 9D1F1C9F5C5D5E51100",1846
40900 DATA "002195E4D5E5CD7AE4E173237223D13E",2202
40910 DATA "08835F30EFE1D1C1F1C926006B291100",1793
40920 DATA "B6195E23567BE6076F7B175F7A17577B",1489
40930 DATA "E6F0B55FC99000000000000000000000",1100
40940 DATA "00000000000000000000000000000000",0
40950 DATA "00000000000000000000000000000000",0
```

References to assembly language commands below assume you are using an assembler which uses Zilog Z80 mnemonics. Assemblers of this type are widely available in the Public Domain, and from other suppliers. MAC supplied with the PCW uses 8080 mnemonics. The hex values for the commands are given in most Z80 books, which can be directly entered into SID.

TIMINGS

The main reason for using machine code is speed. The amount of time instructions take to execute are listed in most Z80 books. The PCW inserts a "wait state", a delay of one clock cycle (0.25μS), for every memory access. So the timings given need 0·25μS adding for each memory access, e.g.

Mnemonic	Hex	μS@ 4Mhz	μS on PCW	Notes
INC r	3C	1·00	1·25	
NOP	00	1·00	1·25	
LD r,(HL)	7E	1.75	2·25	
INIR	EDB2	5·25	6·00	B≠0
INIR	EDB2	4·00	4·75	B=0
INI	EDA2	4·00	4·75	
IN A,(n)	DB n	2·75	3·25	

Note that LD r, (HL) has 0·5μS added to the timing, 0.25μS to fetch the opcode and the other 0.25μS to fetch the contents of memory location HL.

The fastest way to input a large amount of data into memory is to use a long list of INI's, this reads a value from the port held in register C, stores the value in memory location HL, and then decrements B and increments HL. The fastest way to read in two channels is to use INI's interleaved with EXX instructions. EXX switches to other register set, this takes 1·25μS. In this way two "arrays" in memory can be filled with data, e.g.

```
LD HL,400  ;START OF FIRST ARRAY
LD C,176   ;ADC CHANNEL 0
EXX        ;OTHER REGISTER SET
LD HL,800  ;START OF FIRST ARRAY
LD C,177   ;ADC CHANNEL 1
INI        ;START CONVERSION ON
            CHANNEL 1
EXX
INI        ;GET RESULT,STORE,
            AND START CONVER-
            SION ON CHANNEL 0.
EXX
INI        ;GET RESULT,STORE,
            AND START CONVER-
            SION ON CHANNEL 1
... etc ...
```

This is fast but uses up a large amount of memory. The INIR instruction is useful for sampling one channel (this is used in the 'scope program). This is similar to the LDIR instruction but copies the values from a port (in reg. C) instead of from memory. A maximum of 256 values can be read at once (set B=0). To get more than this NOP's can be inserted between INIR instructions to equalise the timing, e.g.

```
LD C,176   ;CHANNEL 0
LD B,0     ;256 INPUTS
INIR       ;READ 256 VALUES
            WITH 6μS PERIOD
NOP        ;1·25μS DELAY
INIR       ;READ ANOTHER 256
            VALUES
... etc ...
```

INTERRUPTS

Note that all of the above timing assume that interrupts have been turned off (using DI). The PCW is interrupted 50 times per second, leaving these switched on will really mess up the timings.

Next month: Linear Power Supply for the 8-Channel ADC.

REPORTING AMATEUR RADIO

Tony Smith G4FAI

RALLIES FOR ALL

Throughout the year amateur radio rallies, hamfests, exhibitions and conventions, large and small, are held across the United Kingdom, and it is worth stressing that you don't have to be a licensed radio amateur to attend these events.

There is also much of interest for short wave listeners, and electronic hobbyists generally. There is usually a demonstration radio station; specialist clubs covering many aspects of radio communication attend to publicise their particular activities; there are lectures or presentations; traders are often present, selling both components and commercial equipment; there is usually a good selection of second-hand items; and there are sometimes other attractions of interest to the whole family.

A few of the events taking place in the next month or so include West Manchester Radio Club Summer Rally on 22nd August [0204 24104 for details]; Galashiels & District ARS Open Day [0835 22686] and Torbay ARS Mobile Rally [0803 526762], on 29th August; Bristol Radio Rally, incorporating a Computer and Electronics Fayre [0275 834282], Milton Keynes & DARS Radio Boot Sale [0908 660798], and Telford Amateur Radio Rally [0952 770922], on 5th September; the Scottish Amateur Radio Convention, Glasgow [041 882 5753], on 11th September; the Isle of Wight Rally [0983 567665] on 18th September; the Harlow Amateur Radio and Computer Show [0850 487863] on 26th September, and so on.

Even if you are not an amateur, why not have a day out that's 'different' to sample at least one small part of the world of amateur radio?

MW DXING

Apart from shortwave listening, medium wave DXing also has a band of enthusiastic followers who tune in to stations from home and abroad which just cannot be heard on a normal domestic radio set-up, at least not without the addition of a specialised aerial such as a m.w. loop.

I am reminded of this activity by the 11th edition of the British DX Club's booklet *Radio Stations in the United Kingdom* which lists all l.w., m.w. and v.h.f./f.m. stations in the UK in frequency order, with power used, location of station and parallel frequencies.

It also has several pages of interesting information about both official and unofficial broadcasters, restricted service licences (special event stations), and how to send reception reports to broadcasters. Good value at £2.00 UK, or 5xIRCs overseas, this useful booklet, 30 pages x A5, is available from the address below.

I occasionally indulge in a little m.w. DXing myself and have been encouraged by this publication, and by the BDXC journal, to try it more often. I have a small rotatable desktop tuned loop aerial and an r.f. preamplifier, feeding into my Sangean world band receiver, which gives surprisingly good results, albeit still capable of improvement!

BDXC specialises in all aspects of DXing, from searching out distant or difficult to hear stations to listening to the major international broadcasters – on the shortwave, medium wave and v.h.f./f.m. bands.

Its monthly journal *Communication* covers the month's developments in international and domestic broadcasting plus many features and articles on specialised subjects. The sample copy I received contained a correspondence section; an article on the history of the BBC's Ottringham transmitting station; the story of broadcasting in Austria; nine pages of the latest DX news, changes in frequency or time of transmissions, etc.; news of development in UK broadcasting, BBC, Independent Radio, and special event stations; QSL Report; a Medium Wave Logbook, reporting m.w. stations from the Americas, Africa/Asia, Europe, and the UK logged by members; a shortwave Tropical Bands Logbook; an H.F. Logbook; long-distance v.h.f./f.m. stations reported; and illegal stations noted on s.w., m.w., and v.h.f..

Further information about BDXC and the aspects of hobby radio it covers, together with a sample copy of *Communication*, can be obtained by sending two first class stamps, or 2xIRCs [overseas], to British DX Club, 54 Birkhall Road, Catford, London SE6 1TE.

ATV-CB BROADCAST

There is very little crossover between Amateur Radio and Citizens Band Radio in this country although many UK radio amateurs were introduced to radio communication originally through CB. In fact, no mention of CB is ever made in *Radio Communication* journal of the Radio Society of Great Britain as a matter of policy, and advertising for CB equipment is not accepted.

It was interesting, therefore to read about an entirely different relationship recently in *Amateur Radio*, journal of Australia's national amateur organisation, the Wireless Institute of Australia.

Last September, Melbourne's Omega Radio Club, described as Australia's premier CB club, celebrated the 12th anniversary of its fortnightly u.h.f. CB broadcast by televising it through the Melbourne amateur TV repeater.

The programme lasted one-and-a-quarter hours and created an interest in watching amateur TV among many CB operators who wanted information on antenna dimensions and beam direction for best reception. Guest speaker was a radio amateur from the RAAF-Williams Radio Club who talked about the history of the repeater and general aspects of amateur TV.

The regular Omega Club broadcast normally has a guest speaker and CB news announcements followed by a callback or "breaker" session. The added element on this occasion was amateur TV and during the broadcast many listeners tried, with some success, to adjust their domestic TV sets to receive the picture. In fact, one ingenious would-be viewer 60km from the transmitter used two VCRs as preamplifiers to obtain a good picture!

Those who were unsuccessful were promised another transmission on request later when they were ready to test reception. The Omega Club itself is hoping to hold further ATV-CB sessions. Radio amateurs in the area had a callback session on the 2-metre amateur band to discuss the broadcast and commented favourably on the joint project.

I must admit, I'm quite impressed by this story from "down under". Some of the stories one hears about CB here are not too complimentary, but I have heard about activities by more serious minded operators too. If there are any joint amateur radio/CB activities in the UK I would certainly like to know about them, and if they are of sufficient interest will be happy to describe them in this column.

KEY COLLECTING

Collecting Morse keys is a hobby in its own right. They can often be picked up at amateur rallies, etc., as described above, but also in other places, in junk shops, at ordinary car boot sales, etc., and it is my experience that once the word gets round that you are interested in collecting them people sometimes offer you keys "out of the blue".

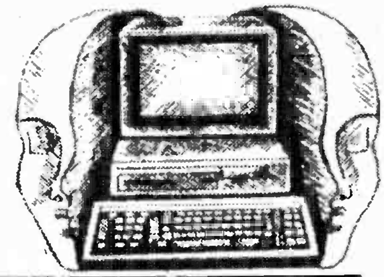
If you really get into it, you are looking at some beautiful instruments made over a hundred years ago. These are pretty rare of course, but not entirely unobtainable.

An interesting, and more readily available, range of keys could actually be the basis of an intriguing collection in its own right. This is the Key WT 8 Amp, the standard British military key of WW2 and afterwards, often available at rallies for about £5.

I have recently completed a survey of reported versions of this key, receiving details from collectors and users round the world. Over 100 different versions have been reported, made in six different countries, and the full 17-page report and listing, including details of their original use in some cases, was recently published in *Morsum Magnificat*, the Morse magazine.

For those interested, the issue number is MM28, and a copy can be obtained, price £2.20 UK, or overseas £2.25, from G.C. Arnold Partners, 9 Wetherby Close, Broadstone, Dorset, BH18 8JB.

INTERFACE



Robert Penfold

IN last month's *Interface* article we started to consider the PC's games port for use in general interfacing applications. In this article we will consider this topic further, and will take a detailed look at the digital and analogue inputs of the games port.

On The Button

As explained last month, there are four digital inputs on the games port ("button 4" to "button 7"), and these would normally be used to read the fire-buttons of the joysticks. Four inputs are needed because the games port can accommodate two joysticks, and each joystick can have two separate fire-buttons.

High level languages often have facilities for reading the fire-buttons, and in GW BASIC the STRIG function can be used. Note that this will only work if a STRIG ON instruction is used to effectively switch on the games port. This function may be very useful when using the games port for its intended purpose, but it is not particularly useful for general interfacing purposes. It does have a potential advantage in that it can be used to determine whether an input has been activated since the last time that the STRIG function was called. However, for most purposes it is easier to read the inputs directly.

The games port is read at hexadecimal address 201, or decimal address 513. The fire-button inputs are at bits 4 to 7 of this address. Presumably this is why these inputs are designated "button 4" to "button 7", rather than simply being numbered 1 to 4. In an interfacing application these inputs would most probably be used independently to read various status outputs.

In order to read just one input line it is merely necessary to bitwise AND the returned value with the correct masking number. Table 1 shows the correct masking number to use for each fire-button input. As an example of reading one of the inputs, this GW BASIC command will read "button 5" and print the returned value on the screen.

```
PRINT INP(513) AND 32
```

The value returned is 32 if "button 5" is high, or 0 if it is low. When an input is high, the returned value is always equal to the masking number used. Of course, when an input is low, the returned value is always 0. The fire-button inputs have standard TTL characteristics, and will drift to the high state if they are simply left floating. If you enter this program line the value printed on the screen should therefore be 32. If "button 4" is connected to the 0 volt rail, or a joystick is connected to the games port and the appropriate fire-button is operated, a value of 0 should be returned.

Table 1

INPUT	MASKING NUMBER
Button 4	16
Button 5	32
Button 6	64
Button 7	128

Analogue Inputs?

Technical information on the workings of the game port's analogue inputs has proved to be elusive. The manuals supplied with add-on games port cards mostly provide nothing more than a port connection diagram. However, you only need to take a brief look at a games port card in order to realise that it does not provide a comparable facility to the analogue port of the BBC computers.

The basic setup seems to consist of four simple timer circuits feeding into an input port. The variable resistors in the joysticks act as the resistances in the CR timing networks. The input port that reads the outputs of the timers seems to be the lower nibble at the same address which is used to read the fire-buttons.

Presumably the timers are triggered by writing the appropriate value to an address in the block occupied by the games port (200 to 207 in hexadecimal). A software routine then monitors the timer outputs, and steadily increments a count stored in memory. When an output goes low, the count for that channel is stored in a byte of memory. The higher the resistance of a joystick potentiometer, the longer the pulse length, and the greater count obtained.

Crude Method

This is a very crude method of analogue to digital conversion, but it is adequate for a simple pointing device such as a joystick. Although it is theoretically possible for a system of this type to offer high resolution and excellent linearity, as implemented on the PCs it does not seem to provide either. The true resolution seems to fall some way short of eight bits, and the linearity is very poor indeed. As far as general analogue interfacing applications are concerned, there is a major problem in that the inputs read a resistance, and not an input voltage.

Despite these limitations, the analogue inputs of the PC games port do have some potential for user add-ons. However, it has to be emphasised that they are likely to be totally unsuitable for any application that requires a high degree of precision. These inputs should only be used for non-critical applications where moderate degrees of error will not have dire consequences.

Sensing

The obvious way of using the games port in sensing applications is to use sensors that provide variable resistances. The sensors can then be wired direct to the games port in exactly the same manner as the joystick potentiometers. Clearly there will not be suitable sensors available for many sensing applications, but there are a few types of sensor which do provide a varying resistance.

For temperature sensing applications a thermistor will give the desired effect. The analogue inputs of the games port have a sensitivity of roughly one kilohm per bit. On the face of it an input resistance range of approximately 0 to 255k is required, but in practice there seems to be a problem with noise giving erratic readings on values of more than about 150k. It is therefore advisable to use a sensor that provides a resistance that always lies within the range zero to 150k.

In the interest of good resolution, the sensor should span a large part of this resistance range during normal operation. A device that provides a resistance of between 75k and 80k during normal use will not be very useful, since it will only provide a range of five or six different readings. A sensor which covers a range of something like 20k to 120k is of much more use, since it covers a range of 100 values.

Some component retailers stock a bead thermistor which has a resistance of 47k at 25 degrees Centigrade. This component does not seem to have a type number, and is usually just described as a "47k thermistor". Its resistance varies from just below 3k at 100 degrees Centigrade, to just over 155k at 0 degrees Centigrade. This would seem to be ideal for general temperature sensing applications, but there are "100k" and "150k" thermistors which might be more suitable if the low temperature end of this range is not of interest.

Connections

Connections of up to four thermistors or other simple sensors to a PC games port is shown in Fig. 1. The numbers in brackets are the games port channel numbers. The analogue inputs are read from GW BASIC using the STICK function. The STICK(0) function returns a value from channel 0, and it also results in readings being taken and stored for channels 1, 2, and 3. The stored

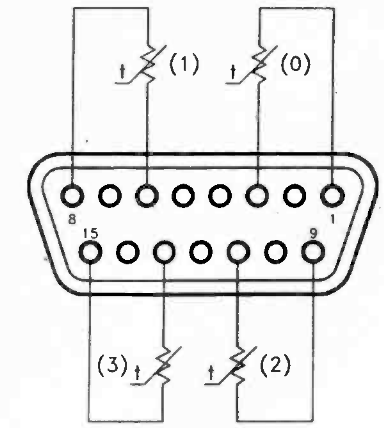


Fig. 1. Connecting thermistors or other simple sensors to the PC games port.

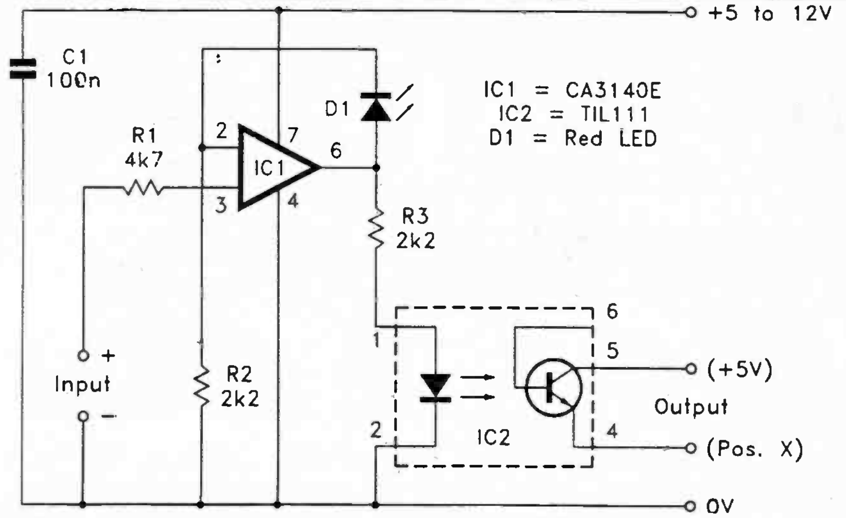


Fig. 2. A simple voltage to resistance converter. This is only suitable for non-critical applications.

values can then be read using the STICK(1), STICK(2), and STICK(3) functions respectively.

A "dummy" reading from channel 0 must therefore be taken before any of the other three channels can be read. For example, these three program lines will result in the four channels of the port being read, with the channel 2 and channel 3 readings then being printed on the screen.

```
10 X+STICK(0)
20 PRINT STICK(2)
30 PRINT STICK(3)
```

Converting readings from a thermistor into corresponding temperatures is a difficult task. There is very poor overall linearity, and increased temperature results in decreased readings. This second problem is due to the fact that normal thermistors have negative temperature coefficients.

It would be possible to note the readings obtained at various test temperatures, and then produce a look-up table from the results. This would not seem to be worth the effort involved though. Where accurate temperature measurement is required it would be much better to use a semiconductor sensor and a proper analogue to digital converter, as described in previous *Interface* articles.

A simple method of sensing such as this is better suited to monitoring applications where (say) something should remain between two critical temperatures. The thermistor can be subjected to these temperatures, and the readings noted. In use a series of readings would be taken and printed out, or the readings could be presented in graph form. An alarm could be operated if the monitored temperature strayed too close to one of the critical levels. Simple monitoring is often adequate for applications of this type, where it is relative rather than absolute temperatures that are of importance.

Light Work

A cadmium sulphide photo-resistor can be used for light level sensing. We are not exactly "spoiled for choice" these days, and at present an ORP12 or equivalent seems to be the only widely available photoresistor. This covers a very wide resistance range, which means that in the present application only a rather limited range of light levels would be accommodated. It might be suitable for some applications though.

Bear in mind that with a photocell it is possible to reduce its effective sensitivity by masking off part of its sensitive surface (which is the zig-zag track in the case of an ORP12). Note that an excessively high resistance can be produced by the ORP12, and that this will cause a reading of zero. This is easily detected, since low resistances never quite produce zero readings.

Voltage to Resistance Converter

Readers occasionally enquire about a voltage to resistance converter circuit for use with PC style joystick inputs. This is possible, and the circuit of Fig.2 will provide a conversion of this type. The circuit is basically just a unity gain buffer stage driving an opto-isolator. D1 is used in the negative feedback path to compensate for the fairly high forward threshold voltage of the l.e.d. in the opto isolator. The collector to emitter resistance of the transistor at the output of the opto-isolator provides the varying resistance for the games port. IC2 can be any "bog standard" opto-isolator.

An input voltage range of roughly 0 to 2 volts is needed. Note that increased input voltage produces reduced readings. This is not of great importance, since the software can be written to take this fact into account. The linearity of the overall system is rather poor, and it is definitely only suitable for non-critical applications.

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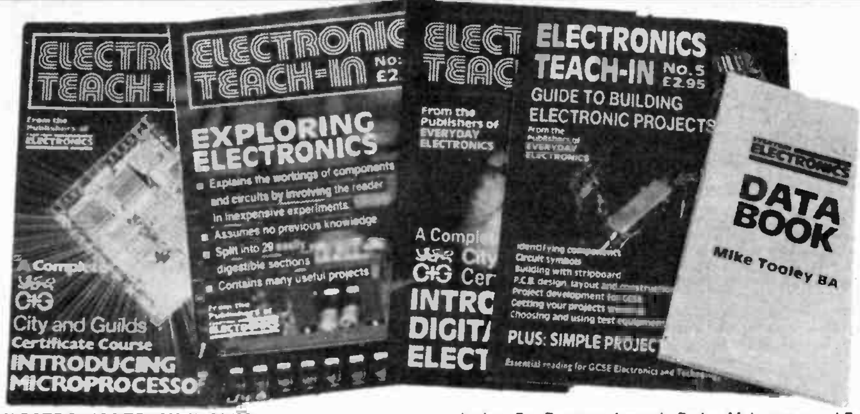

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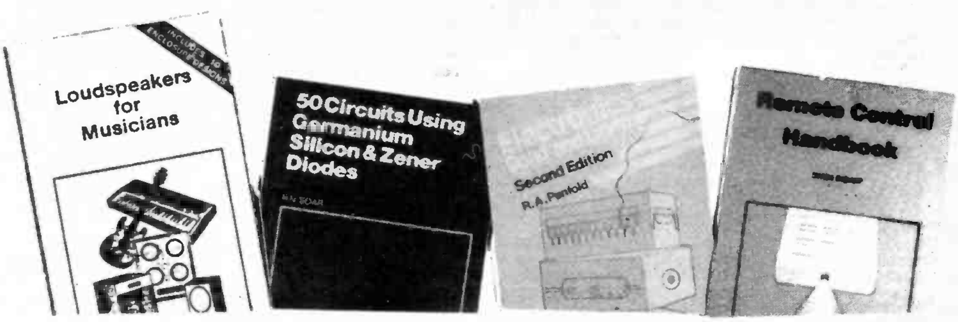

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Published on approximately the first Friday of each month by Wimborne Publishing Ltd., 6 Church Street, Wimborne, Dorset BH21 1JH. Printed in England by Benham & Co. Ltd, Colchester, Essex. Distributed by Seymour, Windsor House, 1270 London Road, Norbury, London SW16 4DH. Sole Agents for Australia and New Zealand–Gordon & Gotch (Asia) Ltd., South Africa–Central News Agency Ltd. Subscriptions INLAND £20 and OVERSEAS £26 (£43.50 airmail) payable to "Everyday with Practical Electronics" Subs Dept, 6 Church Street, Wimborne, Dorset BH21 1JH. EVERYDAY with PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

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