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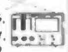
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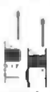
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COMPOSITE VIDEO KITS. These convert composite video into separate H sync, V sync and video. 12v DC. £8.00 ref 8P39R.
SINCLAIR C5 MOTORS. 12v 29A (full load) 3300 rpm 6"x4" 1/4" O/P shaft. New. £22.00 ref 20P22R. Limited stocks.
As above but with fitted 4 to 1 inline reduction box (800rpm) and toothed nylon belt drive cog £45.00 ref 40P8R. 800 rpm.
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SOLAR POWERED NICAD CHARGER. Charges 4 AA nicads in 8 hours. Brand new and cased £6.00 ref 6P3R. 2xC cell model £6.00.

ACORN DATA RECORDER ALF503. Made for BBC computer but suitable for others. Includes mains adapter, leads and book. £15.00 ref 15P43R
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FRESNEL MAGNIFYING LENS. 83 x 52mm £1.00 ref BD827R.
12V 19A TRANSFORMER Ex equipment £20 but OK.
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UNIVERSAL BATTERY CHARGER. Takes AA's, C's, D's and PP3 nicads. Holds up to 5 batteries at once. New and cased, mains operated. £6.00 ref 6P36R.
IN CAR POWER SUPPLY. Plugs into cigar socket and gives 3,4,5,6,7.5,9, and 12v outputs at 800mA. Complete with universal spider plug. £5.00 ref 5P167R.
QUICK CUPPA? 12v immersion heater with lead and cigar lighter plug £3.00 ref 3P92R. Ideal for tea on the movel
LED PACK . 50 red, 50 green, 50 yellow all 5mm £8.00 ref 8P52

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.
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VHF/UHF TV Receiver, converts RGB or composite monitor into colour TV.
Brand new and cased £19. each REF: EV19P1

INDUCTIVE AMPs £5.00

Made for amplifying a telephone handset for the hard of hearing. However if you hold one against 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.
Just £5.00 each. REF: EV5P3

QUME TERMINALS £27.00

Industry standard. 14" screen (green or amber), 80 col or 132 col mode, VT131, VT100, VT52 emulations, XOn-X off or DTR, baud rates from 50-19, 200, standard char sets
Tested and working including keyboard £27.00
REF: EV27P1

DISC DRIVES BBC MOD £9.00

JVC 3.5" drive supplied with well explained modification details to enable use with a BBC computer. Price for drive and data £9.00. REF: EV9P1

PS2 KEYBOARD £18.00

Standard 102 key keyboards designed to plug into IBM PS2 AT computers.
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TANDON HARD DRIVES £25

Did you buy a 1640 base unit? These Tandon hard drives are 10mb half heights units, model no TM252.MFM. Offered to you at less than a 1.44mb floppy! Price £25.00. REF: EV25P1

CTM644 COLOUR MONITORS £79.00

Refurbished monitors suitable for many home computers standard RGB input. £79.00 EACH
REF: EV79P1

RABBIT VIDEO SYSTEM £29

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 downstairs etc. Transmits via 2 wire system. Retails at £60.00 our price £29.00 REF: EV29P1

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MONITORS Mitac 14" SVGA .39DP £174 ref BPCM02, Mitac 14" SVGA .28DP £202 ref BPCM01.
MEMORY 256K Simm 70ns £8.40 ref BPCMI1, 1MB Simm 70ns £26.40 ref BPCMI2, 4MB Simm 70ns £96 ref BPCMI3
MICE 2 button serial mouse with 3.5" s/ware. £8.40 ref BPCMI6, 3button serial mouse with 3.5" s/ware £9.60 ref BPCMI7.
KEYBOARDS 102 AT UK standard keyboard £18.60 ref BPCMI4, Deluxe keyboard 102 AT UK £26.40 ref BPCMI5.
SOFTWARE MS DOS V5 OEM version. £39.60 ref BPCMI8, MS WINDOWS V3.1 OEM version. £42 ref BPCMI9.
MOTHERBOARDS 286-16 Headland chipset £46.80 ref BPCMB1, 386SX-33 Acer chipset £82.80 ref BPCMB2, 386SX-40 UMC with 64K cache £110 ref BPCMB3, 486SX-25 UMC with 64k cache £191 ref BPCMB4, 486DX-33 UMC with 256k cache £378 ref BPCMB5, 486DX-66 UMC with 256k cache £515 ref BPCMB6.
FLOPPY DRIVES 1.44mb 3.5" drive £32.34 ref BPCDD05, 1.2MB 5.25" drive £38.40. 3.5" mounting kit £5 ref BPCDD07.
HARD DRIVES 42MB IDE 17ms £99 ref BPCDD01, 89MB IDE 16ms ref BPCDD02, 130MB IDE 15ms £215 ref BPCDD03, 213MB IDE 14ms £298 ref BPCDD04.
VIDEO CARDS 256k C&T 8 bit SVGA card £19.20 ref BPCVC01, 512k Trident 9000 16 bit SVGA card £31.20 ref BPCVC02, 1MB Trident 8900 16 bit SVGA card £45 ref BPCVC03, 1MB Cirrus AVGA3 16.7M colours £48 ref BPCVC04, 1MB Tseng multimedia £82.80 ref BPCVC05.
ADD ON CARDS Multi I/O card 2 serial, 1 parralel, 1 game, 2 floppy, 2 IDE hard drives. £11 ref BPCAOC01, ADLIB sound card with speakers £37 ref BPCAOC02, Orchid sound card with speakers £63 ref BPCAOC03.

EXAMPLES OF COMPLETE SYSTEMS

386SX-33 SYSTEM
386SX-33 board at £82.80, case £51.60, 2MB ram £52.80, 42MB drive £99, 512SVGA card £31.20, 3.5" FDD £32.34, multi I/O card £11 SVGA colour monitor £174, 102 k/board, £25 build fee if required. Total £579.34
486DX-33 SYSTEM
486Dx-33 board £378, case £51.60, 2MB ram £52.80, 89MB drive £166, 512 SVGA card £31.20, 3.5" FDD £32.34, multi I/o card £11, SVGA monitor £174, 102 k/board £18.60, £25 build fee if required. Total £939.84.
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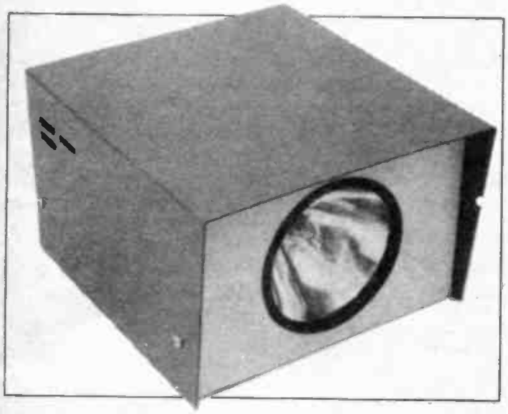
EVERYDAY WITH PRACTICAL
ELECTRONICS
INCORPORATING ELECTRONICS MONTHLY

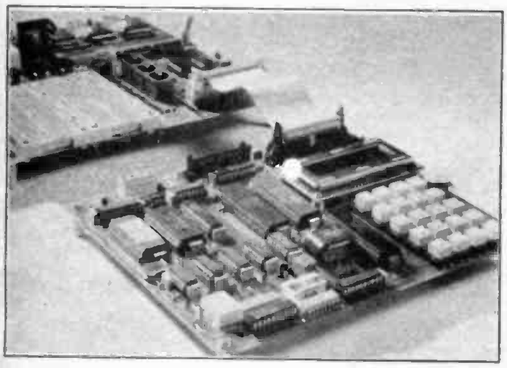
VOL. 22 No. 7 JULY 1993

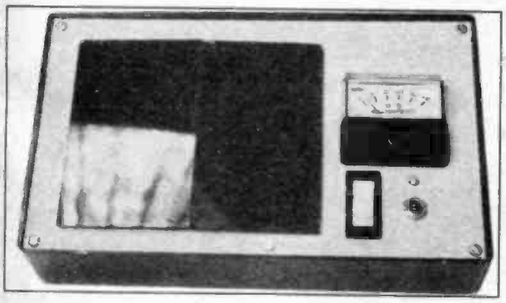
The No. 1 Independent Magazine for Electronics, Technology and Computer Projects

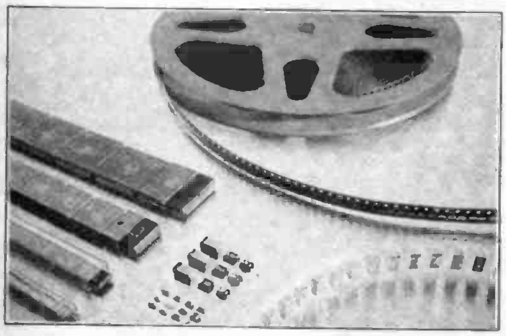
ISSN 0262 3617

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









Our August '93 Issue will be published on Friday, 2 July 1993. See page 475 for details.

Projects

Series

Features

NEXT MONTH

FREE **INSIDE EVERY ISSUE**

GREENWELD 48-page SUMMER SALE CATALOGUE

EXPERIMENTAL ELECTRONIC PIPE DESCALER

Do you suffer from furry pipes? Clogged conduits? Calcified Kettles? Quite a few readers do, it seems. The problem, of course, is due to "hard" water containing calcium, which tends to precipitate onto the surfaces of pipes, kettles, etc, forming the familiar "scale". In addition it can cause scum and lack of lather, resulting in the need for extra detergent and other problems.

Not so long ago the only cure was a large and expensive chemical filter, but recently several new claimed solutions have appeared. Some of these are electronic, mains-powered "black boxes" supplying a signal to a coil of wire placed around the incoming water pipe. We show you how to build such a unit for under £20.

AUDIO AMPLIFIER DESIGN, ENGINEERING OR ALCHEMY?

Can you trust performance tests?

There are two fundamental, but mutually contradictory beliefs in the field of audio, and these can be summarised as:

1. All competently designed audio amplifiers, used within their ratings, will sound the same, and:

2. All things in an audio system are important – so that even the nature of the wiring which is used to interconnect the pieces will alter the sound of the system.

In this short series of articles John Linsley Hood investigates the tests and the claims and looks in a balanced way at how they can be justified, if indeed they can.

BICYCLE ODOMETER

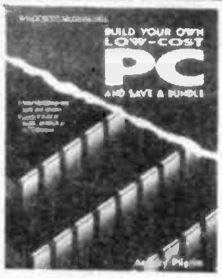
Computerised odometers are available from cycle shops, these give distance, average speed, elapsed time, maximum speed etc. However many cyclists are only interested in the distance of their leisure trip and this unit is designed for them. There is, of course, the added pleasure of building it on a rainy day when cycling is not much fun.

EVERYDAY WITH PRACTICAL ELECTRONICS

AUGUST ISSUE ON SALE FRIDAY, 2nd JULY

ELECTRONIC, HOBBY AND COMPUTER BOOKS

Just a few of the more popular titles from our enormous range - full details in cat.



Build Your Own IBM Compatible and Save a Bundle 2nd Edition
190 x 240mm, 240 pages, soft cover, publication date 1991
Aubrey Pilgrim.
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Ever looked through a computer magazine and found that you can buy boards and parts to build a PC? This book explains all that you will need to know about buying boards, what you need for your applications, how to put a PC together, precautions, etc. Now anyone can build a custom designed PC for much less than a professionally built system would cost, and the only tools you'll need is a set of screw drivers and a pair of pliers.

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Troubleshooting and Repairing Personal Computers 2nd Edition
190 x 240, 675 pages, soft cover, publication date 1991.
Art Margolis.
£18.95 Order Code: MH119
A technical guide to component level fault finding in PC's and other home computers. More advanced than the "Save a Bundle" books, this text deals with the nuts and bolts of the electronics on computer boards, voltage levels, memory addressing, processor modes, diagnostic software, SMT repair techniques, ic pinouts, symptoms gallery, etc. A must for the more technically able, repair technicians, and anyone who needs to know in more detail how computers work.

Computer Technician's Handbook
Art Margils
234x182mm, 571 pages, soft cover.
Price: £24.95. Order Code: MH158
A fully up to date reference book for those involved in computer repair and those wishing to learn more about the subject. Hands on instruction to mend all the latest home or personal computers from descriptions of common 32 bit processors, large dynamic RAM's, to tips on surface mount chip replacement and soldering techniques, this book has it all.

Troubleshooting and Repairing Audio & Video Cassette Players & Recorders
Homer L Davidson.
190x240mm, 414 pages, soft cover.
Price: £15.95. Order Code: MH161
A guide to repairing domestic electronic equipment at all levels from cleaning to component level fault finding. Items covered include personal stereos, ghetto blasters, portable cassette recorders, car and home CD players, VCR's and camcorders. Hint and tips are available for all makes of equipment plus complete schematics for selected items and manufactures. This coupled with a clear text and diagrams make this book a must for any repair technician, or anyone else who has lost hope of having domestic equipment repaired.

Latest Intelligence
190 x 240mm, 300 pages, soft cover publication date 1990.
James Tunnell and Helen Sanders.
£15.95 Order Code: MH129
A dictionary of military, aerospace, and police vernacular and terminology. Ever wonder what all 10 codes used by police and others mean? Speculated about what frequencies are used for military and government communications? Well it's all in this book. A godsend for radio listeners and operators, journalists and anyone who wants to delve into the grey world of secret(ive) communications. Buy it before they ban it.

Pirate Radio Stations - Tuning Into Underground Broadcasts
190 x 240mm, 180 pages, soft cover, publication date 1990.
Andrew Yoder.
£13.95 Order Code: MH130
An entertaining book about the activities of pirate radio station operators, guaranteed to make any straight laced radio regulatory official have an attack of apoplexy. Anyone with even slightly anarchist tendancies will thoroughly enjoy this book, and will probably encouraged to have a go at their own radio station. (Please note this is just an advert for a book; we are not trying to subvert UK radio regulations-really!)

Troubleshooting and Repairing Fax Machines
Gordon McCombs.
232x185mm, 188pages, soft cover.
Price £13.95. Order Code: MH162
Fax machines appear to be complex pieces of electronic equipment that only skilled engineers can repair. This is not necessarily so, servicing and some repairs can be carried out by most users providing certain guide lines are followed. This book guides you through maintenance and repair of all types of fax machines with a few tools, step by step and can save you a small fortune on repair bills since most office equipment repair centres can hardly be said to be cheap.

Troubleshooting and Repairing VCR's 2nd Edition
190 x 240mm, 400 pages, hard cover, publication date 1991.
Gorgon McComb.
£23.95 Order Code: MH102
A guide to fault finding, maintenance and repair of video recorders, for non-experts. This book takes you through all the basic cleaning and repair techniques, that do not appear in the user manuals. Sections on what to tweak and what not, when to consult a professional, what do when coffee is spilt inside a VCR, etc. Save a fortune on unecessary repair shop visits.

Sound Synthesis
130 x 210, 160 pages, soft cover, publication date 1990.
Terence Thomas
£13.95 Order code: MH104
A guide to analogue and digital sound synthesis circuit techniques. Ever thought of building a synthesiser or modifying one you own already? Then this book has all you need to know-over a hundred circuits complete with PCB layouts, anything from voltage controlled filters to MIDI to ports.

Build Your Own Test Equipment.
190 x 240mm, 280 pages, soft cover, publication date 1991.
Homer L. Davidson.
£13.95 Order Code: MH106
The title says it all, this book carries designs for all types of test equipment. If you are involved in audio, rf, computers, or household equipment repairs, and working to budget this book will have something for you. It also contains information on the tools required, how to solder, how to make strip board circuits and PCB's.

Optical Illusions
Stan Gibilisco
234x185mm, 118pages, soft cover.
Price: £7.95. Order Code: MH167
A collection of over one hundred intriguing mind begging illustrations that delves into scientific enigma via an entertaining look at visual illusion. Pictures that will have you see shapes, colours, motions, and patterns that in reality aren't there.

Model Railroad Scenery and Detailing
Albert A. Sorensen
233x186mm, 353 pages, soft cover.
Price £15.95. Order Code: MH172
A book that no model railway enthusiast can afford to be without, Model Railroad Scenery and Detailing is full of hints and tips for construction of authentic looking scenery, rolling stock, and layouts. Topics covered include: scenery design, special effects, lighting, safety, soldering airbrushing, track laying and ballasting, plus much more.

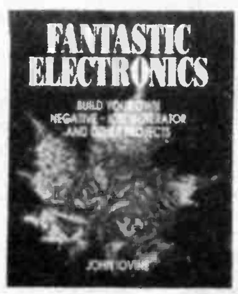
The Laser Cookbook
190 x 235mm, 404 pages, soft cover, publication date 1988.
Gordon McComb.
£18.95 Order Code: MH133
A hands-on introduction to laser theory and operation, with over 80 practical and easy-to-follow projects. These projects range from simple acoustic modulation of laser beam to super-accurate interferometers that precisely measure the speed of light, light wave-lengths, and light frequencies. Readers wanting to increase their knowledge of this subject should look no further than "The Laser Cookbook".
"....provides a fasinating tour through the world of lasers. It is well written, amply illustrated, and lots of fun."
(Modern Electronics)

The Robot Builders Bonanza
190 x 235mm, 326 pages, soft cover, publication date 1987.
Gordon McComb.
£11.95 Order Code: MH136
A collection of almost 100 tried and tested project modules that can be mixed and matched to create a range of intelligent and workable robot creatures. Clearly illustrated and fun to use, this is a must for enthusiasts interested in the area of robots. The 99 different robot components described in this ingenious guide can be combined in an almost endless variety of intelligent and workable robots of all shapes, sizes, and abilities.

Compact Disc Player Maintenance and Repair Manual
190 x 235mm, 244 pages, soft cover, publication date 1987.
Gordon McCombs.
£11.95 Order Code: MH137
Specific guidelines for maintaining and repairing more than a 100 brands of CD players. Packed with quick and reliable answers to the problems of maintaining and repairing CD players, this illustrated do-it-yourself guide takes the apprehension out of first-time repairs. "A valuable accompaniment to a CD purchase...should be in the reference library of anyone who owns or is plannins to own a CD player."
(Midwest Book Review)

Homemade Holograms: The Complete Guide to Inexpenive, Do-It-Yourself Holography
190 x 235mm, 235 pages, soft cover, publication date 1990.
John Lovine
£11.95 Order Code: MH144
This is an ideal 'first-step' into the fascinating world of holograms. The author describes new procedures - using equipment readers can make themselves - that take the complexity out of producing simple white light reflection and transmission holograms of people, as well as computer graphics, and solid objects.

Homemade Lightning: Classical Experiments in Electrostatics
190 x 235mm, 194 pages, soft cover, publication date 1990.
R A Ford.
£11.95 Order Code: MH149
This electronics enthusiast's guide to designing, building, and using classic high-voltage generators and associated equipment. There is a fascinating collection of experiments that reveal the wide-ranging impact of electrostatics on such topics as motor design, aerodynamics, gravity, photography, and meteorology.



Fantastic Electronics
John Lovine.
190x240mm, 220 pages, soft cover, publication date 1993.
Price: £14.95. Order Code: MH165
An eclectic blend of twenty three science and electronics projects for anyone who has an interest in the world around them. Topics covered range from genetics-recombinant DNA and genetic engineering in the home laboratory- to Kirlian photography (auras and other such peculiarities), taking in along the way negative ions, bio-feedback, ELF, Geiger counters, magneto hydrodynamics, plasmas, air pollution, holography, and much more. Not to be missed off any book list.

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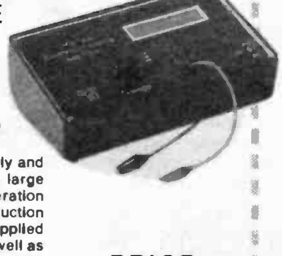

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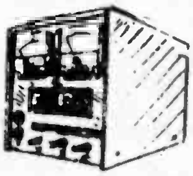

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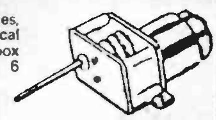

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EVERYDAY WITH PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

VOL. 22 No. 7 **JULY '93**

Editorial Offices:
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Phone: Wimborne (0202) 881749
Fax: (0202) 841692. DX: Wimborne 45314.
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ENVIRONMENTALLY FRIENDLY?

"Green" issues seem to be at the forefront in most media these days and we are no exception. This month we publish another "solar" project to add to those in past issues.

A few years ago such a project as the *Solar Personal Stereo Supply* would have been totally out of the question on the grounds of price alone. Even now the cost of the project (£20 upwards) is high in comparison with its complexity. However, with battery prices ever rising and the heavy use some of them are put to, such a unit could pay for itself by the end of the summer.

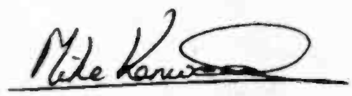
MAGNETOHYDRODYNAMICS

Next month we will describe a rather different "green" project, an electronic descaler. A few months ago a reader sent us a leaflet about such an item, costing over £200, which is now being widely marketed in the UK. What we have done is to ask Andy Flind, one of our "team" of freelance designers, to produce an experimental unit based on the same principles. A unit that you and I can build for less than £20.

The output of our project is similar to that of the commercial item and it should therefore do the same job of preventing limescale build-up in pipes and around taps, shower heads, kettles, etc. It could save on your heating bill and prevent costly repairs.

We will be very interested to hear from readers of their experiences with the unit in use over the coming months. Apparently the science behind the effect of magnetism on liquids is called magnetohydrodynamics and hopefully this science will become better understood in the future. It has suffered rather from the almost unbelievable claims of increased performance and fuel savings in petrol engines when a simple magnet is attached to the fuel line.

As Barry Fox said a few months ago, we have yet to see independent proof that such devices work as claimed. However, it seems to be generally accepted that magnetism can indeed prevent limescale build-up in water systems and a range of devices (mainly ceramic magnets) are now being fitted to commercial and domestic systems.



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Business Manager: DAVID J. LEAVER
Subscriptions: MARILYN GOLDBERG
Editorial: Wimborne (0202) 881749
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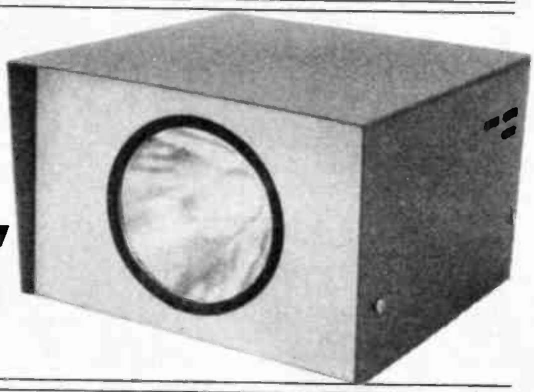
XENON STROBOSCOPE



CHRIS WALKER

Study the behaviour of rotating or vibrating objects by "freezing" the action. Can also be used to create special effects for home photography.

THE stroboscope described in this article is a mains-powered piece of apparatus which provides brief bursts of intense blue-white light at a flash rate adjustable from about 3Hz up to 260Hz. A xenon flash tube is used as the light source, and an external trigger input is provided so that the flashes may be synchronised to an external signal source.

This is **not a suitable project for anyone who is not experienced in building mains powered equipment** see the Electrical Safety section

FREEZE

A stroboscope is a very useful piece of gear in the laboratory or workshop since it can be used to "freeze" the motion of a rotating or vibrating object. This can be very useful if one wishes to observe the dynamic behaviour of the object.

For example, the vibration in an unbalanced drive shaft can be studied in "slow motion", or the mode of vibration of a loudspeaker cone. Other interesting objects to study include the movement of guitar strings, tuning forks, electric drills, electric food-whisk beaters, electric fans, model aeroplane engines etc.

A fast-dripping tap is a fascinating subject. With the stroboscope you can freeze the water drops in mid-air or, perhaps even more impressive, make the drops travel slowly upwards from the sink into the tap!

Furthermore, if the stroboscope is calibrated then the frequency of the moving object can be measured by freezing the object's motion and reading the frequency off the stroboscope dial. More on this later.

A stroboscope can be used in photography to create multi-image effects (this could be especially useful when the external trigger input is used), and it can also provide special effects in discos and on the theatrical stage although the power output of this unit is rather limited for such use.

WARNINGS

Be careful when using a stroboscope on or near machinery. Remember that although the machine's motion may appear frozen it is still very much in motion and could cause injury if touched.

A few people who suffer from epilepsy may be sensitive to flashing lights, and flashes at relatively low frequencies may induce a seizure. **Anyone experiencing dizziness, blurring of vision, headaches or general lack of concentration whilst using the stroboscope should discontinue use immediately.**

XENON TUBE

Xenon (pronounced zennon) is a colourless, odourless gas. It occurs in trace amounts in air and is relatively non-reactive. (The word Xenon comes from the Greek meaning "something strange"!)

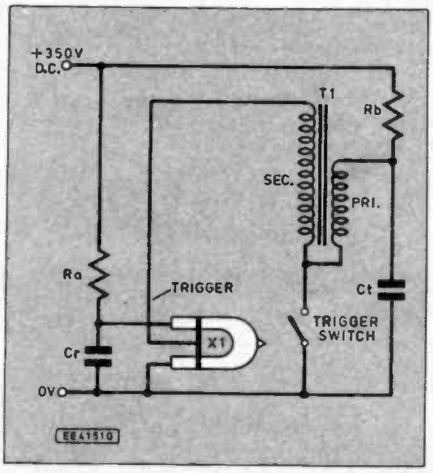


Fig. 1. Basic trigger arrangement for "striking" the Xenon tube.

The flash-tube used in the Xenon Stroboscope is very similar to those used in photographic flash-guns. It is simply a xenon-filled glass tube with an electrode at each end and a third "trigger" electrode fastened to the *outside* of the glass.

BASIC CIRCUIT

The circuit in Fig.1 shows how these tubes are often used. The reservoir capacitor C_r charges up to about 350V via resistor R_a. At the same time the trigger capacitor C_t charges via resistor R_b.

Specification:

Power Supply:	Mains 240V, 50Hz a.c. Current consumption 150mA max.
Light Source:	Xenon tube Energy input per flash: Greater than 100mJ below 60Hz; 30mJ at 250Hz
Trigger:	Range A: 3Hz to 26Hz (180/min to 1560/min) Range B: 9Hz to 86Hz (540/min to 5160/min) Range C: 30Hz to 260Hz (1800/min to 15600/min) External trigger input: 3V to 18V Positive-edge triggered. Opto-isolated for safety. Maximum flash rate approx. 300Hz

When C_r is charged a p.d. of 350V then exists across the ends of the xenon tube X1 but the tube will not conduct since the xenon gas is an insulator. To make the gas conduct it is necessary to apply a brief high voltage pulse in excess of 4000 volts to the trigger terminal on the tube.

This is achieved by discharging the trigger capacitor C_t through the primary winding of the trigger transformer "T1" shown in Fig.1. When the trigger switch is closed the surge of current through the transformer primary induces a high voltage spike into the secondary winding which is applied to the trigger electrode on the tube.

Under "rest" conditions the xenon atoms in the tube are electrically neutral; this is why the gas will not conduct – there are no free charged particles to permit conduction. However, under the intense electric field created by the trigger pulse, electrons are literally torn off the xenon atoms and they start to accelerate towards the positive electrode at the end of the tube. This is called "striking" the tube.

As they accelerate, these rushing electrons collide with other xenon atoms and knock further electrons into conduction. The process rapidly grows into an avalanche until there is a huge torrent of electrons crashing along the tube.

Under these conditions the gas exhibits a very low resistance and capacitor C_r discharges its load through the tube in a brief, high current surge. This current excites the xenon atoms and causes the emission of light.

The gas remains conductive until the reservoir capacitor is almost fully discharged and the current flow through the tube drops below a "holding level", upon which the free electrons re-combine with the xenon atoms once more.

The capacitors then recharge and, after a short delay which depends on the values of resistors and capacitors used, the tube is ready for firing once again.

CAPACITOR

The choice of reservoir capacitor greatly influences the performance of the circuit and the brightness of each flash.

Electrolytic capacitors have the advantage of a high capacitance but they also exhibit a relatively high "power factor" due to their structure. This means that the maximum rate at which they can discharge is limited by the inherent internal resistance and inductance of the capacitor. It also means that they waste energy by heating themselves up during the charge/discharge cycle.

The shorter the flash duration, the brighter the flash will be (for a given energy put through the tube) so it makes sense to use a type of reservoir capacitor with the smallest possible power factor so that it can discharge rapidly and dissipate its energy in the tube, not the capacitor.

After experimentation, the author found that polypropylene capacitors give the best results. They have a power factor several hundred times lower than most electrolytics.

MAIN CIRCUIT

The entire circuit for the Xenon Stroboscope is shown in Fig.2. Mains power is supplied via on/off switch S1 and the circuit is protected by fuse FS1 (which should be a slow-blow type to cope with the current surge at switch-on). Transient suppressor (varistor) VDR1, connected directly between mains Live and Neutral, helps to remove any mains-borne spikes (high voltage pulses) which could damage some of the components within the stroboscope.

Diode D1 provides half-wave rectification of the a.c. mains and the resulting current-pulses flow through resistor R1 and charge up the smoothing capacitor C1. The d.c. voltage across C1 will be relatively stable at about 340V, which is the *peak* value of the a.c. mains.

Current flows via resistors R2 and R3 to charge up the tube reservoir capacitor C2. Resistors R2 and R3 have to dissipate a large amount of heat at high flash rates, hence the use of two resistors in parallel to share the load.

Current also flows from the smoothing capacitor C1 through resistor R4 to charge up the trigger capacitor C3. Resistor pair R5 and R6, Zener diode D4 and capacitor C5 provide a stabilised 12V power supply for the oscillator circuit described next.

OSCILLATOR

The internal trigger pulses are generated by IC2 which is a CMOS version of the popular 555 timer i.c. Any low power 555 i.c. should work in this application, e.g. ICM7555, TS555CN, TLC555C etc.

The frequency of oscillation is determined both by the setting of variable resistor VR1 and by which capacitor is switched into circuit by the range selector switch S2b. The three capacitors C6, C7 and C8 provide the three switched frequency ranges A, B and C as described in the specification.

The other pole of the range switch S2a selects the source of trigger pulses – from the output of IC2 (pin 3) for ranges A, B and C or from opto-isolator IC1 if the 'external trigger input' position is selected.

OPTO-ISOLATOR

Applying a p.d. across the external trigger input sockets SK1 and SK2 causes a current to flow through the l.e.d. within the opto-isolator IC1. The infra-red light emitted as a result switches on the transistor within IC1, creating a p.d. across resistor R8 when rotary switch S2 is in the "Ext." position.

The opto-isolator is included as a safety feature to ensure that there is no electrical connection between the mains-linked stroboscope circuit and any external device connected to it. **It must not be omitted from the circuit.**

A sharply rising voltage across R8 charges capacitor C4 and creates a brief positive pulse at the *gate* terminal of MOSFET TR1. This, in turn, briefly

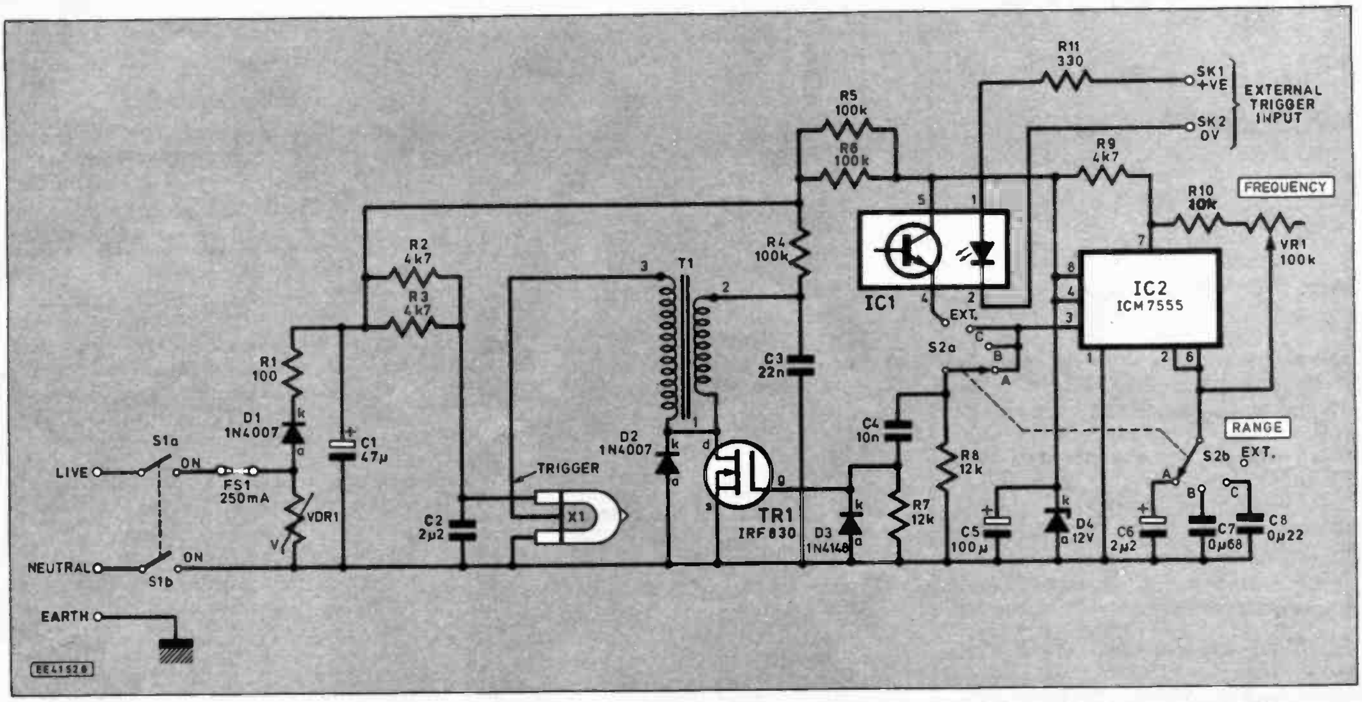
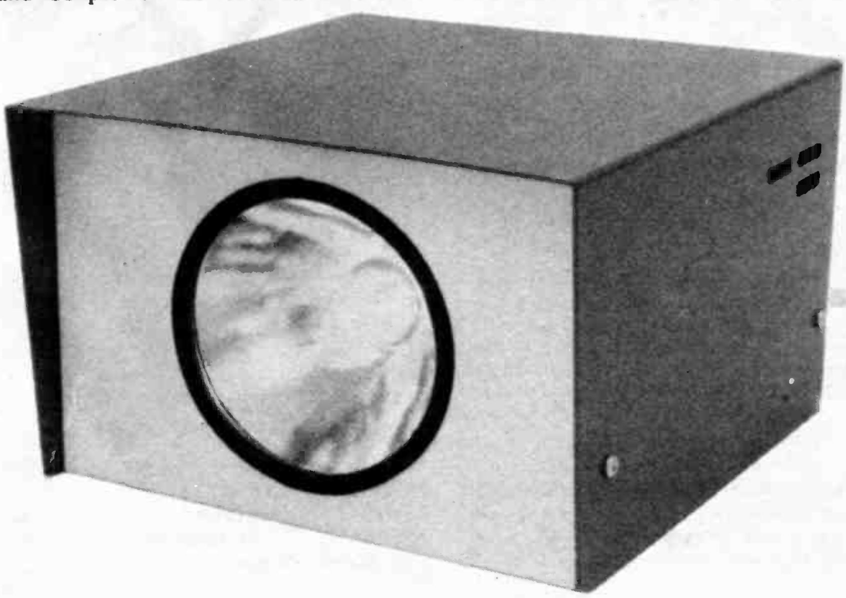
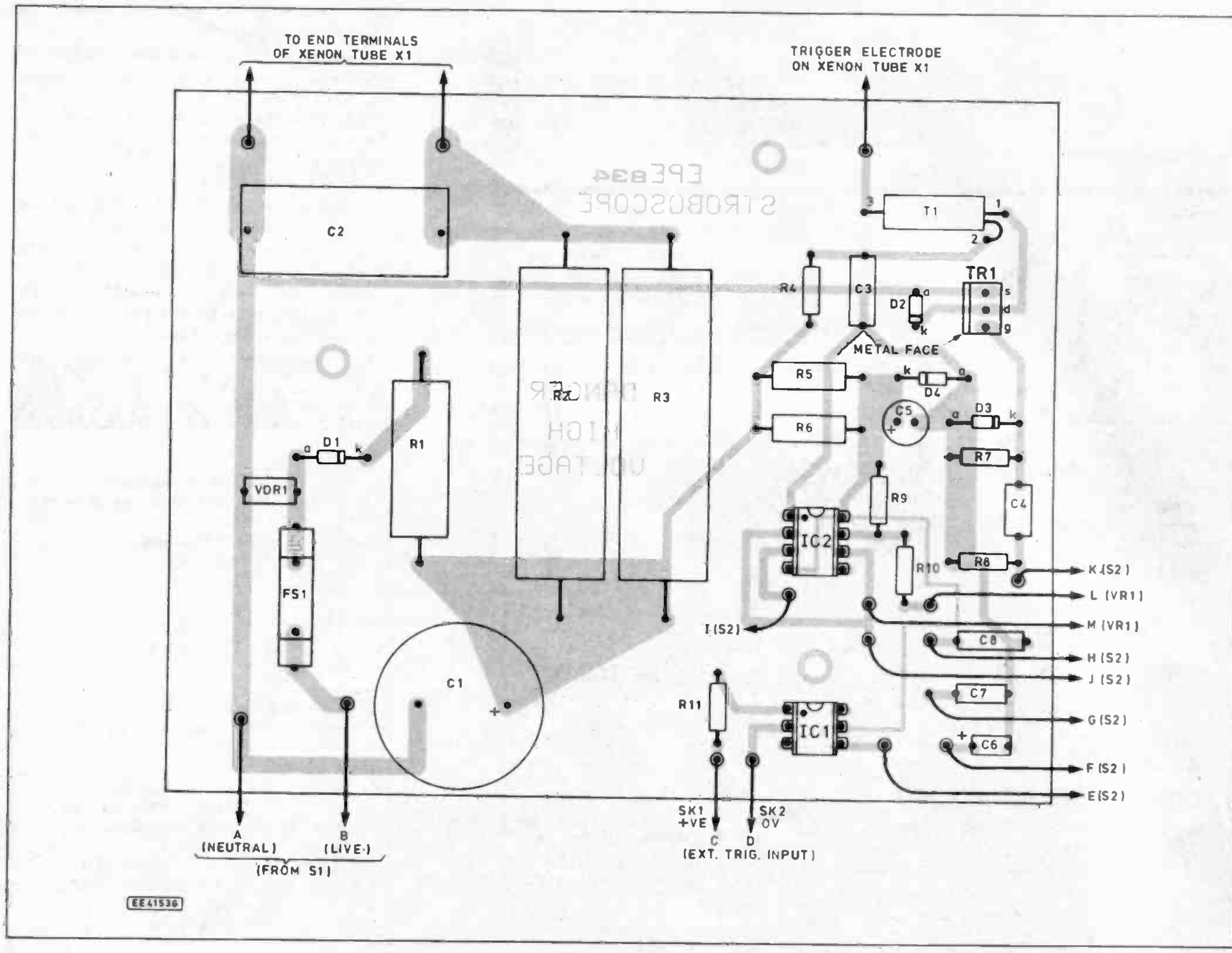


Fig. 2. Complete circuit diagram for the Xenon Stroboscope. The opto-isolator IC1 MUST be included to safely isolate and protect any external trigger device from the high voltage circuit.





reduces the resistance between *drain* and *source* allowing capacitor C3 to discharge through the primary winding of trigger transformer T1.

The voltage induced into the secondary winding of T1 is applied to the trigger terminal on the xenon tube X1. This trigger pulse strikes the tube, causing it to conduct, and capacitor C2 then discharges through the xenon tube producing a bright flash of light.

Diode D2 protects the MOSFET by quenching the high voltage back e.m.f. which is generated by transformer T1 after each trigger pulse.

The capacitor and resistor values have been chosen so that the energy dissipated in the tube per flash is reduced at higher frequencies. This is done to prevent the tube from overheating and thus severely reducing its operating life.

The maximum flash rate is limited by how fast the capacitors can re-charge between each flash. With the values given, the maximum rate is about 300Hz. Attempting to operate above this frequency will simply result in the tube "misfiring" – no damage will result.

ELECTRICAL SAFETY

***THIS IS NOT A BEGINNER'S PROJECT.* The entire circuit board is connected directly to the mains and must be treated with great respect. MAINS ELECTRICITY CAN KILL!**

We do not wish to dissuade readers from building this useful piece of gear but, please, **if you have any doubts about any aspect of construction then seek advice from** someone with the necessary experience.

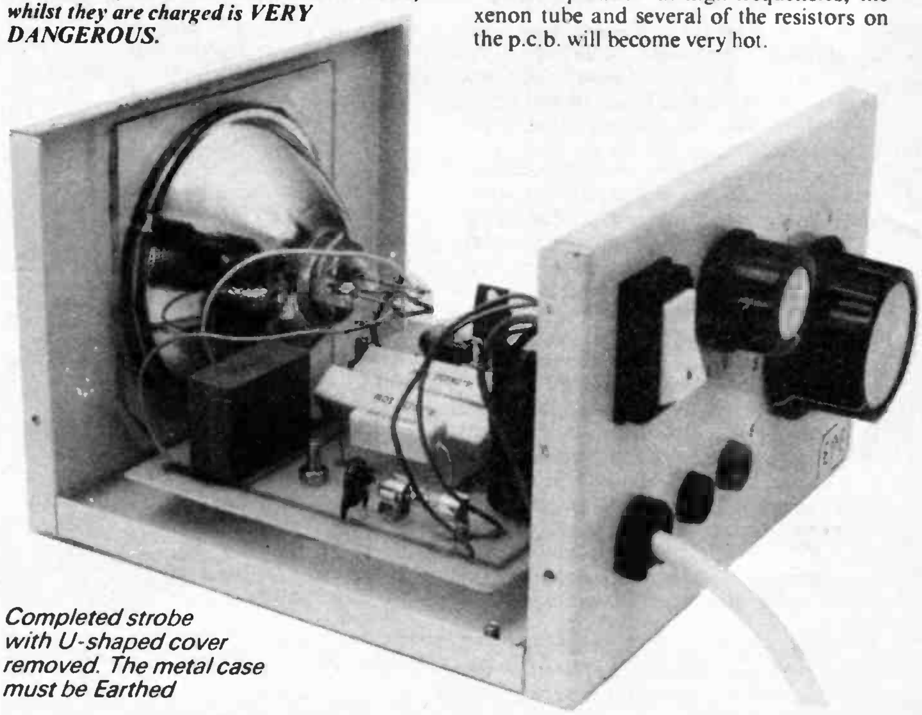
The components used **must** be new (not salvaged from Grandad's old valve radio) and of high quality. The power rating of the resistors, and the voltage rating of the capacitors **must be at least that specified** in the components list.

Capacitors C1 and C2 will retain a hazardous charge for several seconds after switching off. Contact with these capacitors (or with any conductor connected to them) whilst they are charged is VERY DANGEROUS.

If a metal case is used for the stroboscope **it must be earthed.** The unit should **not be operated until it is completely encased.**

Should it prove essential to run the circuit with the printed circuit board exposed then plug the mains lead into an R.C.D. circuit breaker to minimise the chances of a fatal electric shock. The metal tab of MOSFET TR1 will be at 340V above earth during use; be careful not to touch it.

After operation at high frequencies, the xenon tube and several of the resistors on the p.c.b. will become very hot.



Completed strobe with U-shaped cover removed. The metal case must be Earthed

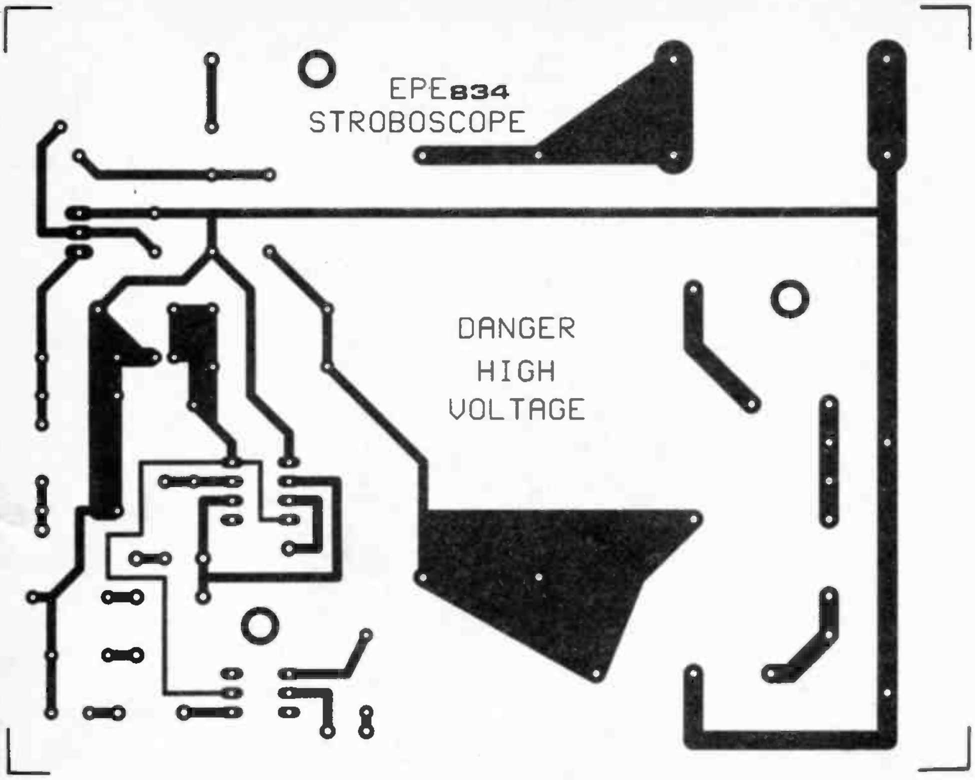


Fig. 3. Printed circuit board component layout (far left) and full size copper foil master pattern (above).

CONSTRUCTION

Despite the earlier warnings, construction of the Xenon Stroboscope is quite simple. The circuit is built on a printed circuit board and the foil pattern and the component layout is shown in Fig.3.

Commence construction of the p.c.b. by soldering in the physically small resistors, the small capacitors, the diodes, fuse holder and the trigger transformer T1.

The lead connections for the trigger transformer shown in Fig.3 are for the "4kV trigger transformer" as specified. Connections for other transformers may differ and it would be wise to check before mounting on the p.c.b.

As usual, it is recommended that d.i.l. sockets are used for IC1 and IC2. Notice that IC1 is a six-pin device and it will be necessary to cut down a larger d.i.l. socket (e.g. 8-pin) using a small hacksaw before mounting on the p.c.b.

Double check the values and the positioning of all components. Make sure that the diodes are placed the correct way around; as usual, the band around the body of the diode indicates the cathode (k) lead.

Insert the MOSFET TR1 with its metal tab adjacent to diode D2. Although TR1 is equipped with a heatsink tab it should not become at all warm in use so no additional heatsink is required. Transient suppressor VDR1 is not polarity-conscious and can be fitted either way around.

Solder into place the large capacitors C1 and C2 paying particular attention to the polarity of electrolytic capacitor C1. When fitting the large power resistors (R1 to R3, R5 and R6), they should be mounted about 10mm *above* the board to allow air to circulate freely around them.

Solder sixteen flying leads onto the p.c.b. for later connection to the off-board components. These leads should be made using flexible, insulated copper wire.

Finally, insert the two integrated circuits into the d.i.l. sockets and place a 250mA anti-surge fuse into the fuse clips.

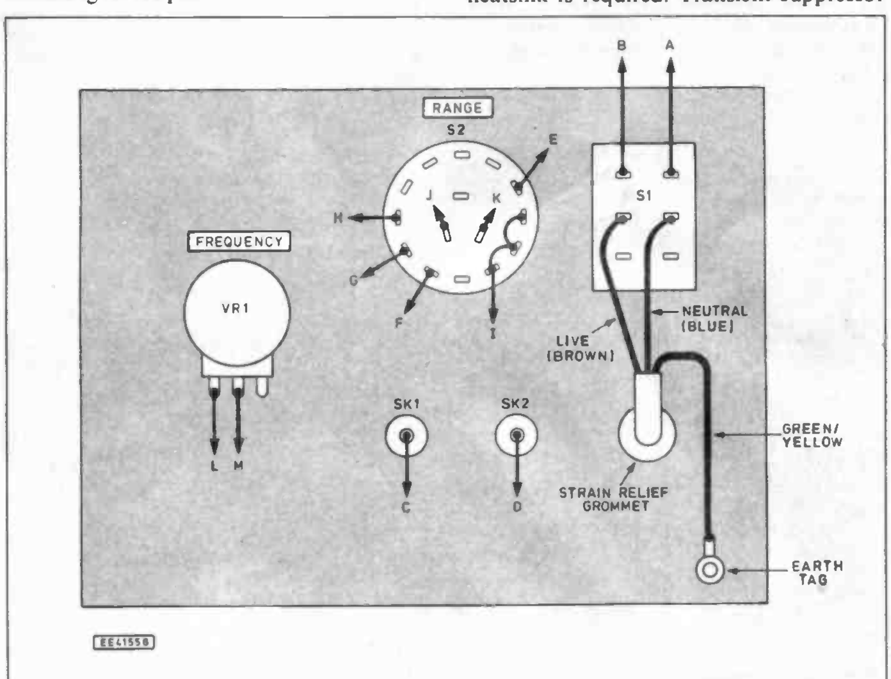


Fig. 5. Wiring from panel mounted components to circuit board. Letters A to M indicate connections to p.c.b. shown in Fig. 3.

COMPONENTS

Resistors

R1	100 3W wirewound
R2, R3	4k7 10W wirewound (2 off)
R4	100k
R5, R6	100k 1W carbon (2 off)
R7, R8	12k (2 off)
R9	4k7
R10	10k
R11	330

All 0.6W metal film unless stated otherwise.

Potentiometer

VR1	100k rotary carbon, lin.

Capacitors

C1	47µ radial elec. 450V
C2	2µ2 400V polypropylene
C3	22n 400V polyester
C4	10n polyester
C5	100µ radial elect. 25V
C6	2µ2 35V tantalum bead
C7	0µ68 polyester
C8	0µ22 polyester

Semiconductors

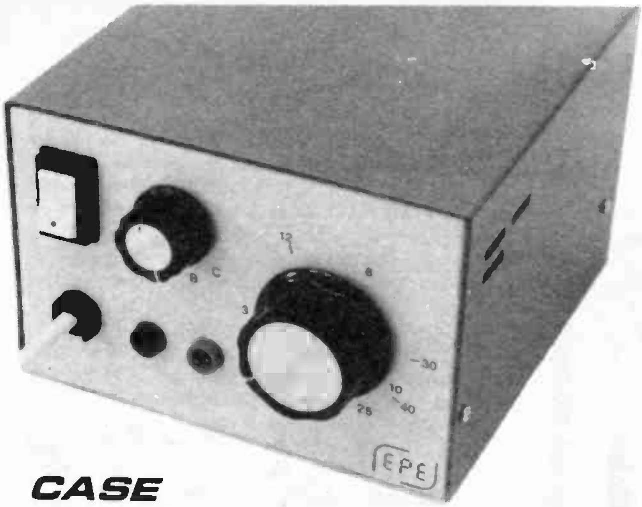
D1, D2	1N4007 1000V PIV silicon diode (2 off)
D3	1N4148 silicon diode
D4	BZY88C12V 12V 500mW Zener diode
TR1	IRF830 power MOSFET
IC1	Opto transistor isolator
IC2	Low power 555 timer i.c. (e.g. ICM7555, TS555CN, TLC555C etc.)

Miscellaneous

X1	Xenon flash tube. U-shaped strobe type, rated at 4 joules (or greater) per flash.
T1	4kV trigger transformer to match xenon tube X1
VDR1	250V mains transient suppressor
S1	Double-pole mains rocker switch
S2	3-pole 4-way rotary switch
SK1, SK2	4mm panel mounted socket (2 off)
FS1	250mA anti-surge fuse (20mm) with two p.c.b. mounting clips.

Printed circuit board available from the *EPE PCB Service*, code 834; aluminium case 150mm x 150mm x 100mm; parabolic reflector; clear Perspex; p.v.c. beading to trim reflector hole; Earth solder tag; knobs (2 off); strain relief grommet; 4BA nuts, bolts and spacers; connecting wire; 8-pin d.i.l. sockets (2 off, one cut down to 6-pin); 3-core mains lead; rubber feet for case (4 off).

Approx cost guidance only **£29**



CASE

The prototype Stroboscope is housed in an aluminium instrument case measuring 150mm x 150mm and 100mm high. The photographs show how the xenon tube and reflector are mounted on the front panel and the controls mounted on the rear panel. A plastic case could be used, if desired, in this case no metal parts should pierce the case i.e. use nylon fixings and insulated plastic spindle controls.

Drill the case to accommodate the controls – on/off switch S1, range switch S2, frequency control VR1 and external input sockets SK1 and SK2. The point where the mains cable enters the case should be fitted with a strain-relief grommet to prevent the cable from being pulled out.

When planning the layout of the case, try to keep the frequency controls and their wires as far as possible away from the xenon tube otherwise interference from the latter could cause spurious operation.

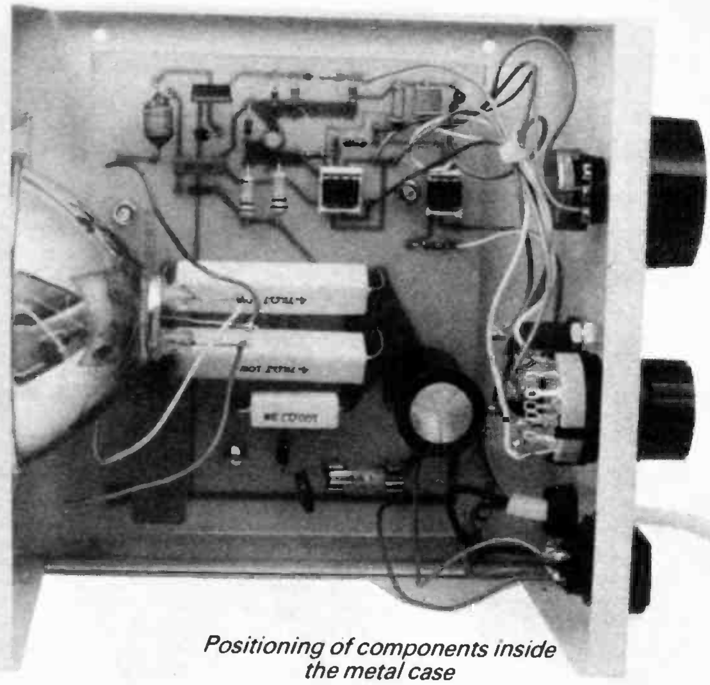
If a metal case is used, *it is most important that it is earthed for safety.* Remember that you may not be the only person ever to use this device. The earth wire in the mains lead must be fastened to a solder tag which is then bolted to the metal case. Scrape any paint away from the contact area to ensure a good connection.

REFLECTOR

The light output from the Stroboscope will be vastly increased by placing the xenon tube at the approximate focal point of a parabolic reflector. Constructors could have a go at making their own reflectors, but something suitable should be obtainable from an old torch, or a car side-light or fog-lamp – a visit to a scrap yard could yield results. Ideally, a reflector diameter between 70mm and 120mm will be well matched to the size of the xenon tube.

A metal reflector is preferable to one made from plastic since the xenon tube can become quite hot at high flash rates and a plastic reflector will melt! The shape of the hole at the back of the reflector will need modifying with a file to accommodate the xenon tube; the latter can be held in place using high melting point adhesive, e.g. Araldite.

A large hole, slightly smaller than the diameter of the reflector, should be cut out of the case. One method of doing this is to mark the required hole size on the case and then drill a ring of smaller holes just inside this mark. The disc is then removed by cutting between the holes with tin-snips or an Abrafile and the final hole can be filed out to full size. The hole can be lined with a strip of slotted p.v.c. beading; this produces a smart appearance, much better than a sharp, cut edge.



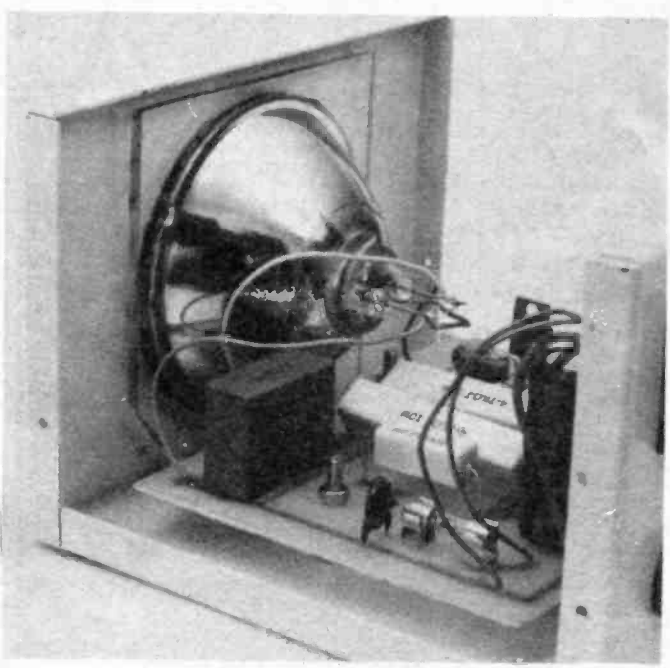
Positioning of components inside the metal case

A sheet of clear Perspex is glued behind the hole (inside the case) and the reflector/tube assembly is then glued onto the Perspex, see Fig.4. This method of mounting is particularly important if a metal reflector is used since it ensures that the reflector is well insulated from the earthed case. Unless the trigger electrode on the xenon tube can be insulated from the reflector (this is difficult to achieve), earthing the reflector will prevent the tube from striking.

INTERWIRING

The p.c.b. should be securely fastened into the case using three 4BA bolts, 10mm spacers and nuts (nylon bolts if a plastic case is used). It is obviously important that the p.c.b. tracks do not touch the metal case.

Once all the components are fastened into the case, complete the connections between the p.c.b. and the panel-mounted components according to Fig.3 and Fig.5. Note that connection "I" is made to three tags on the rotary switch S2. Route the wires from rotary switch S2 and potentiometer VR1 well away from the xenon tube and its associated wiring.



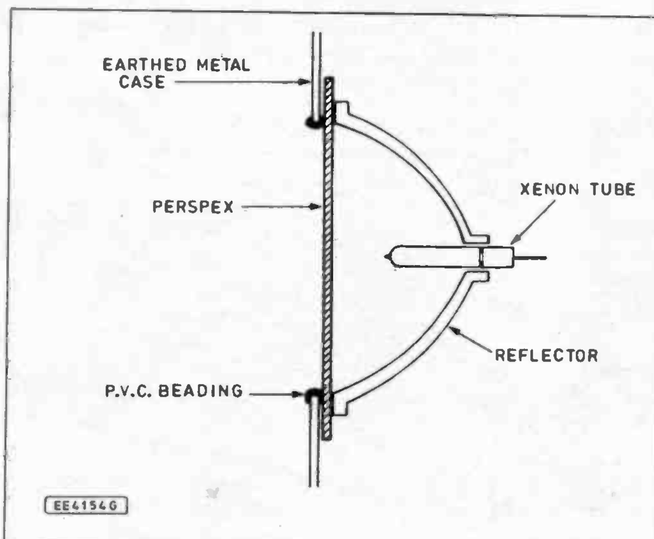
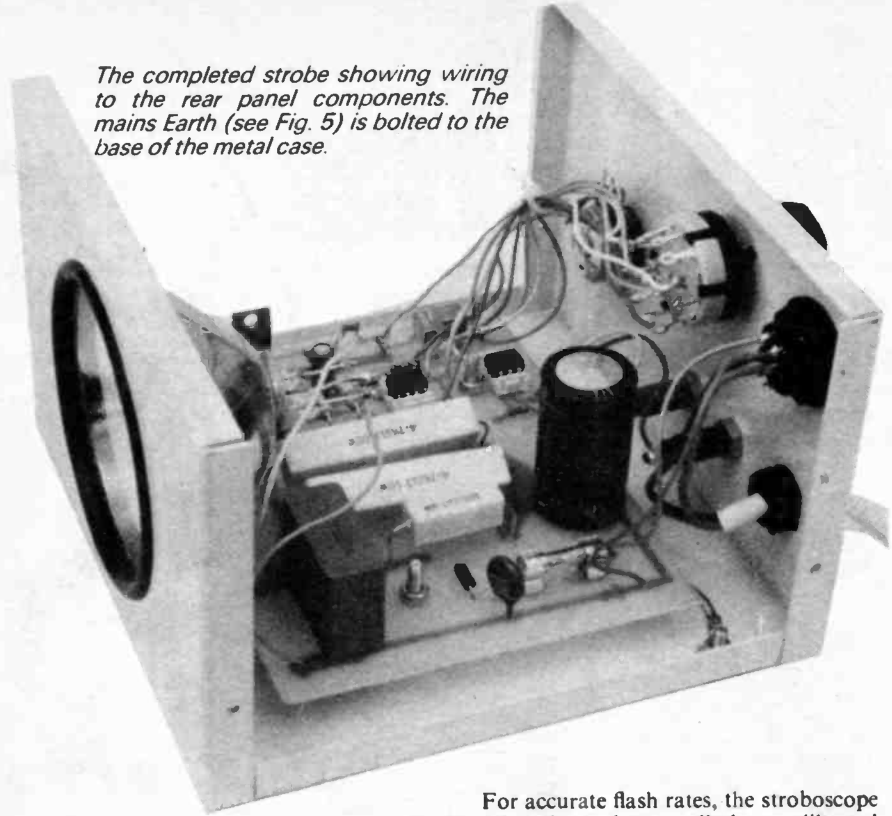


Fig. 4. Method of mounting the tube and reflector inside the case. The Perspex also insulates the reflector from the metal case. Wiring to the tube pins and reflector glued in position is shown left



The completed strobe showing wiring to the rear panel components. The mains Earth (see Fig. 5) is bolted to the base of the metal case.

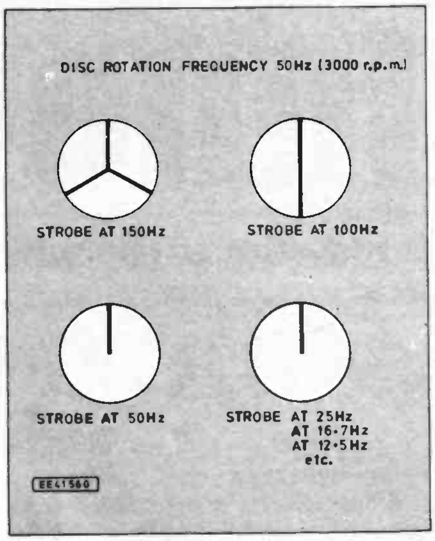


Fig. 6. The effect of "strobing" a rotating disc. (Rotation frequency 50Hz (3000 r.p.m.).)

CALIBRATION

Accurate calibration of the prototype Xenon Stroboscope was not attempted. Instead, two approximate scales were applied around the frequency control knob, one set for ranges A and C (which are related by a factor of ten) and the other set for range B.

For accurate flash rates, the stroboscope can be triggered externally by a calibrated signal generator connected to sockets SK1 and SK2.

It is possible to use a set of tuning forks to calibrate the Stroboscope at higher frequencies. This is achieved by stroboscopically freezing the motion of the fork's tines. The frequency is often stamped on the side of a tuning fork. However, it should be noted that the frequency scale around VR1 is not linear, so detailed calibration does require a large number of tuning forks!

When arresting the motion of an oscillating object in order to assess its frequency, it is necessary to start with the stroboscope at a high frequency and reduce it slowly until the **first** frozen image is obtained. As the frequency is reduced further a second stationary image will be obtained with the flash rate at half the oscillation frequency; the object is then undergoing two cycles of oscillation between each strobe flash, see Fig. 6. □

Innovations

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

GIRLS SHOW THE WAY

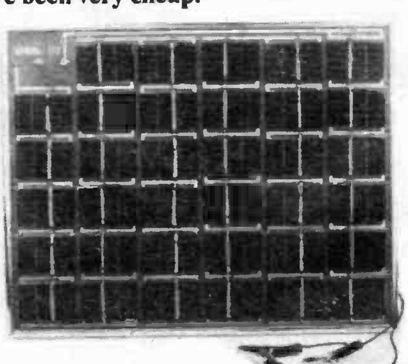
IN an industry which has traditionally seen only a very small percentage of female engineers it is pleasing to find more than half the honours in the 1993 Young Electronic Designer Awards being taken by the girls. Pictured are three of this years winners flanked by co-sponsors Ken Sanders, managing Director of Texas Instruments Ltd (right) and Robert Johnston, Personnel Director of Mercury Communications Ltd. (left).

Senior winner, Philip Pegden (18) (centre) of Tonbridge School, designed a computerised quadraphonic sound effects system for theatres. Intermediate winner Nicola Hay (second left) of Woldingham School in Surrey achieved her success with an electronic device to monitor water contamination in brake fluid, now a requirement of the MOT. Junior winner Emma Lye (second right) of Bancroft's School in Essex won her prize with an electronic elbow, which tests the temperature of a baby's bath water.

Nicola Hay also won "The Texas Instruments Prize" for the most commercially viable project, whilst Richard Coull of Harris Academy in Dundee won the "Mercury Planet Award" for the project displaying the most environmental and socially aware technology with his ioniser to cut carbon exhaust emissions from cars. The awards, organised by the YEDA Trust, were presented by HRH The Duke of York at the Science Museum recently.

NEW SOLAR PANELS

A warning at the end of Maplin's press release about two new solar panels reads "The kit does not come complete with sunlight" – what a pity. At £39.95 and £59.95 each the sunlight would have been very cheap.



Designed for charging sealed lead acid batteries, a blocking diode is built into the circuit to prevent the reverse flow of current from the battery during poor lighting conditions. Four hooks are provided on the back of the panels for easy mounting and 2m of connecting cable with medium size crocodile clips are included.

Each panel is laminated in special resin with an ultra violet inhibited poly-carbonate surface. They are epoxy sealed into an aluminium frame, to withstand the rigors of weather.

The panels can be connected together either in parallel or series to increase the current of voltage output. The smaller version produces an output current of 250mA approx. and can be configured to produce two outputs of 6V at 250mA each, by removing a link on the back of the panel. The larger panel produces 12V at 500mA approx.

Maplin Electronics P.O. Box 3, Rayleigh, Essex SS6 8LR. Tel. 0702 552911. Fax 0702 553935.

Trade in Technology

If you manufacture machines for the production or processing of goods or materials, agriculture or food, either for domestic, industrial or commercial use or can offer designs, know-how or training for the manufacture or processing of specific items, free assistance can be provided to link you with enterprises in developing countries.

Over the past two years the United Nations Industrial Development Organisation (UNIDO) in co-operation with The Technology Exchange Ltd, a UK voluntary organisation promoting the international transfer of technology, have established a series of Techmart events in the developing countries. Venues to date include Beijing, China, Bulawayo in Zimbabwe and New Delhi in India.

Before each event The Technology Exchange Ltd compile an indexed catalogue of end products, materials and processes for which western firms can supply machines, training, designs and formulations or know-how either under licence, by way of a joint venture partnership or by direct contact or sale.

These catalogues are printed by UNIDO and circulated via all the UNIDO national organisations to enterprises seeking technology from abroad and they are indexed by product name to help firms to contact the appropriate source of supply or technical assistance.

Catalogues are now being prepared to cover Techmart events in Tunisia and India. Followed later by Brazil, Costa Rica, Mexico, Vietnam and Zambia. For further information and submission forms contact: The Technology Exchange Ltd., Wrest Park, Silsoe, Bedford MK45 4HS, England. Phone (0)525 860333. Fax: (0)525 860664.

CALL FOR NEW COPYRIGHT LEGISLATION

In 1981 Richard Branson made the front page of the music press with the news that his company, Virgin, had developed a product which allowed music to be electronically delivered direct to stereo systems in the home. That was a successful April Fool's hoax – 12 years on, it's no longer a joke.

In his address to the WIPO Worldwide Symposium on the Impact of Digital Technology on Copyright and Neighbouring Rights, Nic Garnett, IFPI's (International Federation of the Phonographic Industry) Director General, warned of the potential dangers facing the music industry, of falling to anticipate the changes brought about by rapid advances in technology.

"Digital cable audio systems are already in operation and have the capacity to broadcast the entire worldwide inventory of phonograms available on CD, in under six months. It is likely that the transmission of CD quality sound via electronic delivery will not only have some impact on retail sales but also lead to an escalation in the level of private home copying, at least in the short term. At present, there is no existing regime (in respect of communication to the public), to secure the phonogram producers' interests in the case of electronic delivery."

Nic Garnett went on to say, "This is more than a debate about the level of remuneration – copyright legislation lies at the heart of the modern phonographic industry. Approrpiate legislation which carries the exclusive right to authorise or prohibit the reproduction of a phonogram is fundamental to the continuous functioining of the industry. Laws tend to change more slowly than people's behaviour and in the case of electronic delivery, such a delay could prove fatal to the music industry as presently constituted."

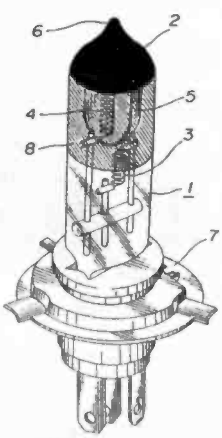
THE THINGS PEOPLE PATENT!

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.

Vehicular lighting device

In UK patent 225112 PIAA Corp. describe an optical bulb (1) for use in a lamp of a motor vehicle. It comprises a main filament (3), and a sub-main filament (4). A multi-layer film (8) is coated over a glass tube at the portion corresponding to the sub-main filament for transmitting yellow light.

When driving at night and meeting a motor vehicle coming from the opposite direction, the sub-main filament is heated and produces yellow light which will not dazzle the driver of an oncoming vehicle.



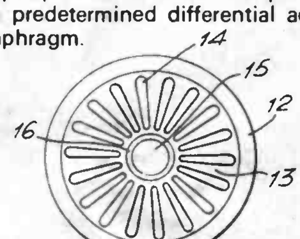
Rechargeable battery incorporating memory

In UK patent 221515 Technophone Ltd. describe a rechargeable battery for portable electronic apparatus such as a cellular telephone. It comprises a housing enclosing one or more rechargeable cells and a memory, such as an EEPROM, for storing information such as the voltage/current characteristics of the battery and/or the number of previous recharge cycles.

This information is indicative of the condition of the cells and can then be used to select a charging programme best suited to the prevailing condition of the battery, and hence optimise the logevity and performance of the battery. Historic information is thus always available whenever the battery is changed so that the most appropriate charging programme can be selected taking into account the full history.

Electrical switches

In UK patent 2251517 The BOC Group plc describe an electrical switch actuated by means of a pressure differential exerted across a diaphragm consisting of a planar sheet of meterial, supported along its periphery (12). It has an unsupported central area (13) and a series of radial elongated indentations (14) to cause the central portion to adopt a first position and rapidly move to a second position with a predetermined differential across the diaphragm.



The invention is particularly useful in conjunction with a positive action (or positive break) switch, i.e. one in which the switch is closed and capable of passing current when in an unoperated position.

A deliberate cut, for example opening a guard, is necessary positively to depress the switch actuator to reverse this condition and open the circuit. With the invention, the snap-acting diaphragm opens the circuit. Preferably the diaphragm is supported across a passageway or nozzle which is assoicated with a switch and which is arranged for communication with a pressure or vacuum vessel. In such cases, the pressure of the vessel acts on one side of the diaphragm and ambient pressure acts on the other side of the diaphragm.

FLUKE

FLUKE instruments have a high reputation for quality and reliability within the electronics Industry. They have recently announced a new range of three Series 10 instruments.

All the family offers a.c. and d.c. volts, ohms, diode test, continuity bleeper, easy to read 4,000 count digital display, autoranging and sleep mode to preserve battery life.

Model 10 is the "no frills", lowest cost model. Model 11 has the addition of VChek and Capacitance with auto or manual ranging from 0·001µF to 999µF and to 9,999µF. Model 12 (shown) combines all the features of the other two plus: Min/Max Record with a Relative Time Clock to take readings over a 100 hours period without the operator, and Continuity Capture which collects intermittent opens and shorts as brief as 250µS.

The Model 10 unit costs £48.95 plus VAT. For more information contact Alpha Electronics PLC, Units 5 & 6, Linstock Trading Estate, Wigan Road, Atherton, Greater Manchester M29 0QA. Telephone: 0942 873434, Facsimile: 0942 873558.

IMAGE RECORDERS

TWO new computer image recorders from Polaroid offer an easy way of turning computer images from your computer screen into professional quality 35mm presentations.

The CI-3000S and CI-5000S operate with virtually all IBM compatible personal computers and the CI-5000S is also compatible with Apple Macintosh II, Quadra and Sun Workstation computers. Polaroid (UK) Ltd., Freepost, Ashley Rd., St. Albans, Herts AL1 5YZ.

New Technology Update

Ian Poole reports on developments in i.c.s, super computers, l.e.d.s and static sensitivity.

THIS month there is a range of ideas to give a wide flavour of some of the latest happenings in the field of technology. Diamonds are being used in a variety of areas to prove their worth. New super high power computers are also appearing as some of the latest technology is put to practical and commercial use. In addition to this we will look at a new silicon l.e.d. and a method for reducing the susceptibility of i.c.s to static damage.

Diamond I.C.s

Everyone naturally thinks of diamonds as being very expensive. This fact will be confirmed by anyone who has bought some diamond jewellery. Despite this there are occasions when diamonds can actually be used to reduce costs.

One area where this has happened is in a specialised microwave i.c. application. Microwave circuits need high current to enable them to operate at the required frequencies. This entails dissipating large amounts of heat. Dissipation is normally not too much of a problem for discrete components, as the components are spaced over a wide area. In i.c.s the component density is very much higher and removing the heat from such a small area can present a very real difficulty.

In one particular i.c. it was necessary to dissipate just over ten watts of power. As the circuit ran too hot when used with aluminium oxide, the normal substance used for the removal of heat, other methods had to be sought. One solution entailed splitting the i.c. up into a number of smaller circuits which could have their heat removed more easily. This was not very satisfactory because it degraded the performance and increased the production costs.

Another solution involved drilling holes in the substrate so that the high power components could be mounted directly onto a specialised heatsink. Not only was this very costly, but it led to fractures in the substrate.

The solution which was finally adopted involved the use of chemical vapour deposition on diamond. This technique has previously only been used in the production of laser diodes. Owing to the fact that the thermal conductivity of diamond is about fifty times that of aluminium oxide the heat is efficiently removed from the substrate.

Although the diamond itself is expensive, the cost of the overall device is reduced because it simplified the production, reducing the number of operations required. In addition to this it enabled the i.c. to run without becoming excessively hot.

Smaller Supercomputers

As technology advances it is becoming possible to place ever more powerful computers into smaller spaces. It was not that long ago that the DEC PDP11 represented a major advance in technology. Now after several years they have been left far behind. In fact some of today's supercomputers are approaching the size of the old PDP11 computers.

In a recent development, Silicon Graphics of California have produced a 64 bit CMOS processor. This new processor allows a computer to operate with up to 18 way processing and enables supercomputers to be designed into reasonable sized cabinets. The new processor operates at extreme speeds, giving a throughput of 300M flops. It can execute up to six instructions every clock cycle.

The basic system architecture allows for up to 36 processors together giving a computing power of 6G flops. However current systems only use up to 18 processors. The larger of the two systems currently on offer can use between 2 and 18, whereas a smaller system uses between 2 and 6.

One of the major problems encountered during the design occurred in the data handling. With the enormous processing speeds available it was necessary to be able to transfer vast amounts of data very quickly and to have access to very large memories. This problem has been overcome by the use of a 256 bit wide bus implementation for data transfer. There is also a 40 bit address which enables it to address up to a terabyte of data. In this way transfer speeds of several gigabytes per second can be attained.

Silicon L.E.D.s

Light emitting diodes are very common in today's electronics. However they are all based around gallium arsenide. This is expensive in manufacture and obviously great precautions have to be taken with handling the chemicals used in the processing - for obvious reasons. As a result many people are investigating the possibility of using a silicon based process. One idea for this was outlined in *New Technology Update* in the November 1992 issue.

Another idea based on a silicon-germanium material is beginning to come to fruition. Researchers at Tokyo University working in conjunction with Hitachi have succeeded in developing a diode structure. Initially it would only emit light at very low temperatures but now the diode structure has been improved so that it will operate at room temperature.

The diode consist of three pairs of very thin alternate layers of silicon and silicon-germanium. In turn these are placed between a "*p*" and an "*n*" type silicon layer. Finally electrodes are placed on these outer two layers to enable the electrical connections to be made.

Getting the structure to operate at room temperature has not been easy. However the basis of the improvement has been attributed to an increase in the amount of germanium in the silicon-germanium layer and the addition of a trace of boron to the silicon layer.

Eventually it is hoped that the diodes will be used as laser diodes, but the day when everyday l.e.d.s are based around silicon technology might not be too far away.

Static Sensitivity

Electro-static discharge or ESD has long been a cause for concern with electronic devices. The effect was brought to the notice of everyone when MOS devices were first introduced. Many people can testify to these problems first hand with a pile of dead devices to show for it.

As the problem became widespread, manufacturers started to place protection diodes within the devices. These precautions were largely successful, but even so care was still needed. Even today manufacturers still have special antistatic areas for working on these i.c.s.

Naturally a large amount of research has been put into investigating the effects associated with ESD and semiconductors in general. From this work there is a growing school of thought which indicates that any semiconductor device should be treated as if it was static sensitive. Even bipolar transistors are not immune. Whilst they may not fail immediately, it has been shown that their long term reliability can be impaired.

With this background, many people are working to make all types of semiconductor devices more immune to the effects of static. In one such investigation engineers at Texas Instruments have discovered that MOS devices are less likely to suffer static damage if the gates have a fingered structure. Their findings show that a 16 finger 0·6μm device failed when the voltage on the gate rose to 13kV. This represented a considerable increase in immunity over existing devices.

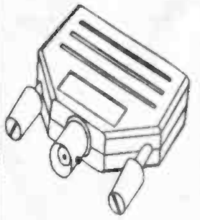
The key to the success of this method has been attributed to the fact that these techniques give a far more uniform potential gradient than more conventional layouts within a device. However as static voltages can rise to exceedingly large values, static precautions will still be needed, although the new designs are less likely to suffer either the short term or long term effects. This will help increase the reliability of electronic equipment still further.

Low cost data acquisition for IBM PCs & compatibles...

A unique range of low cost data acquisition products for IBM PCs and compatibles. Installed in seconds they simply plug directly into either the serial or parallel port. They are completely self contained, require no external power supply and take up no expansion slots.

Each device comes with an easy to use software package (PicoScope, PicoLog or both). C, Pascal, and Basic drivers are supplied for those who want to develop their own software, as is a manual giving full details of the hardware and software. All software supplied on 3.5" disk.

ADC-10



- Up to 24kHz sampling rate from a 386/33MHz machine
- 0-5V Input range
- BNC input connector allows use of standard scope probes
- 30V overload protection
- Parallel port connection
- Includes PicoScope software

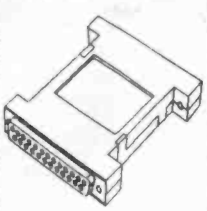
Single Channel 8 bit ADC £49

ADC-16

- Software selectable single ended or differential inputs
- Resolution programmable between 8 and 16 bits + sign
- ±2.5V input range
- 5V reference output
- Connects to serial port
- Includes PicoLog software

8 Channel 16 bit + sign ADC £99

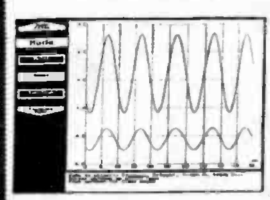
ADC-11



- 15K samples per second
- 0-2.5V Input range
- Digital output
- D25 input connector
- 30V overload protection
- Parallel port connection
- Includes both PicoScope and PicoLog software

11 Channel 10 bit ADC £75

PicoScope

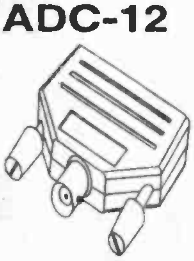


Scope, voltmeter, spectrum analyser

'Virtual instrument' software package for the ADC-10, ADC-11 and ADC-12.

Storage oscilloscope with trigger and timebase. Traces can be printed and saved. Multiple meters on screen. Real time spectrum analysis.

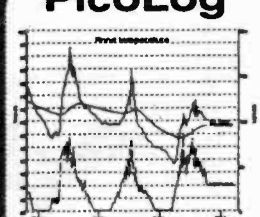
ADC-12



- Up to 18kHz sampling rate
- 0-5V Input range
- BNC input connector allows use of standard scope probes
- 30V overload protection
- Parallel port connection
- Includes both PicoScope and PicoLog software

Single Channel 12 bit ADC £85

PicoLog



Advanced data logging software

Collect samples from 1 per ms to one per day. Scale samples linearly, by equation or by table look-up. Graphical (against time or XY) and text reports can be displayed, printed or exported.

Picolog is also available for the ADC-10: call for details.

Typical application	ADC-10	ADC-11	ADC-12	ADC-16
Oscilloscope	●	●	●	
Voltmeter	●	●	●	●
Spectrum analyser	●	●	●	
Audio sampling	●		●	
Chart recorder emulation		●		●
Temperature measurement	●	●	●	●
Pressure measurement	●	●	●	●
Chromatography				●
Automotive monitoring		●		●
Medical research		●	●	●
Education	●	●	●	●

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SOLAR PERSONAL STEREO SUPPLY

T.R. de VAUX BALBIRNIE

Green power for your personal stereo or radio. Put the sun to good use.

THIS solar power supply unit was designed in response to a request from a reader who is also a personal stereo enthusiast. With regular use personal stereos tend to be expensive on replacement batteries. The reader suggested the use of *solar power* instead and this project provides just that.

VIABLE SYSTEM

Experiments show that using solar cells for this purpose is indeed possible. In tests carried out on sunny days during the British summer there was found to be sufficient power available to operate a personal stereo using a fairly small (10cm × 12cm approximately) solar cell array.

However, this alone does not make a viable system and, in practice, it is necessary to include a pair of nickel-cadmium rechargeable cells and a simple control circuit. This is because conditions need to be ideal to operate the stereo direct. Also, some units may need more current than the solar cells are likely to supply.

Nickel-cadmium cells accumulate charge while the personal stereo is not being used so that the energy is available for use later. They also "fill in" when clouds obscure the sun, or at any other time when the light is not bright enough to provide the full operating current. For this reason, the user will be encouraged to leave the unit in bright light when it is not being used.

Depending on the type of solar cells, even on a dull day, a charge rate of some 15mA to 20mA may be expected. Under bright conditions it may exceed 100mA.

Although the Solar Personal Stereo Supply is really intended for static use – when sitting on the beach, for example – it may be possible to use it while walking or jogging if the unit is attached to the top of a backpack. This will depend to some extent on the choice of solar cells and this point will be explained in more detail later. *Note that, for safety reasons, it is not recommended to use a personal stereo while cycling or operating machinery.*

Although the initial outlay in constructing this unit seems fairly high (see *Shop Talk*) costs are soon recovered especially when the stereo is used for several hours a day.

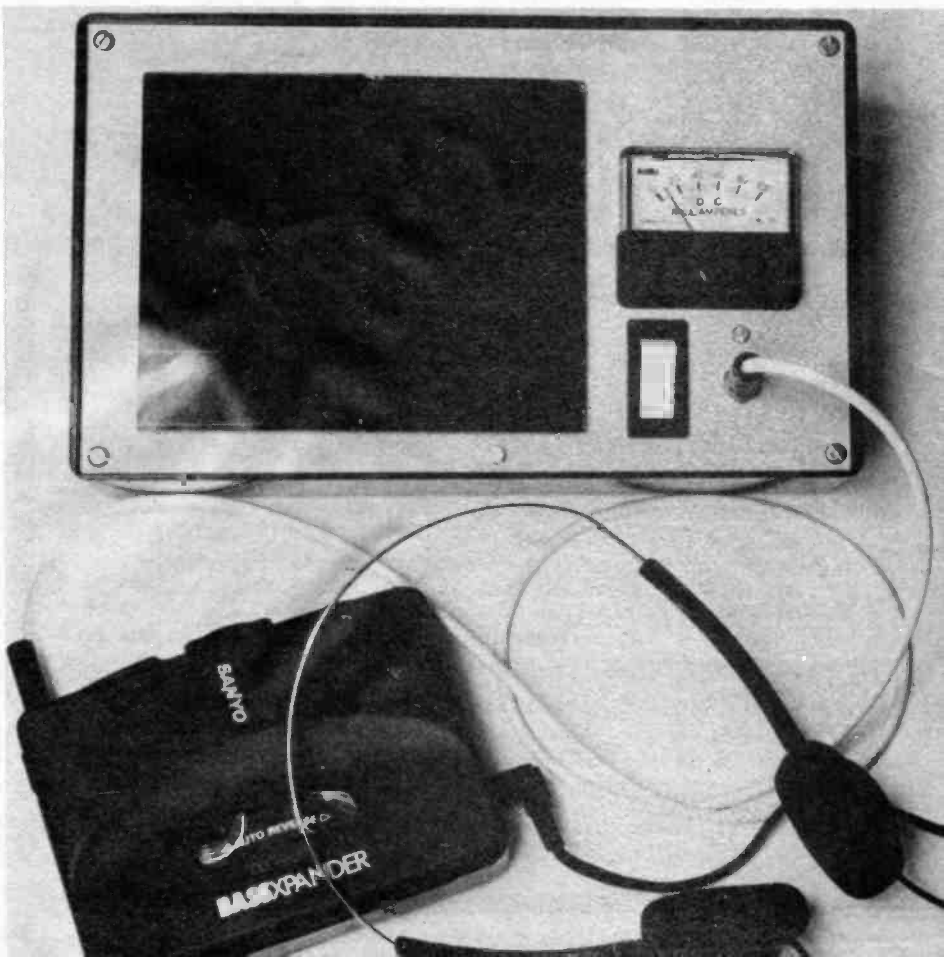
ARRAY OF SUNSHINE

The prototype Solar Personal Stereo Supply was built in a sloping-front (desk console-type) plastic box. The shape of this helps to direct the solar panel sensitive surface towards the sun. Since the price of the box represents a high proportion of the total cost, however it would be possible to use a cheaper one and provide a strut – or simply use a few books – to aim the panel correctly.

The box contains the two nickel-cadmium cells in a holder and the control circuit. There is also space inside for a set of conventional cells. These are optional but will be found convenient to operate the stereo if ever the nickel-cadmium ones are completely discharged. These are larger than cells normally fitted in a "Walkman" so will be more economical in use.

A milliammeter may be mounted on the box to monitor the solar cell output current. Although adding to the cost, it is fun to provide one of these and it helps to aim the panel for maximum efficiency. Readers who decide not to use the meter may reduce the size of the box accordingly. If a meter is not fitted it would be helpful, although not essential, to have a multitester available at the setting-up stage.

A socket is mounted on the front panel of the box and this is used to connect the unit to the power-in socket on the personal stereo. It seems usual for a Walkman to have a miniature (1·3mm) power-type socket fitted for an external d.c. supply to be used. However, some stereos do not have one so here it would be necessary to connect the unit using a set of dummy batteries. Details for this method are given later.



With ample space inside the case, it is appropriate to use somewhat larger rechargeable cells ("C" size) rather than the "AA" size usually fitted in a personal stereo. These can store about three times the energy and will provide around ten hours of operation. A further point is that these larger cells will not be damaged by overcharging even if bright light shines on the solar panel continuously.

SUITABILITY

The Solar Personal Stereo Supply is suitable for use with personal stereos and small radios requiring a 3V input i.e. that usually provided by two standard 1·5V cells and, preferably, requiring no more than 100mA to 150mA. *It is not suitable for devices needing a higher voltage e.g. 4·5V or 6V, so check the number of cells before beginning construction work.*

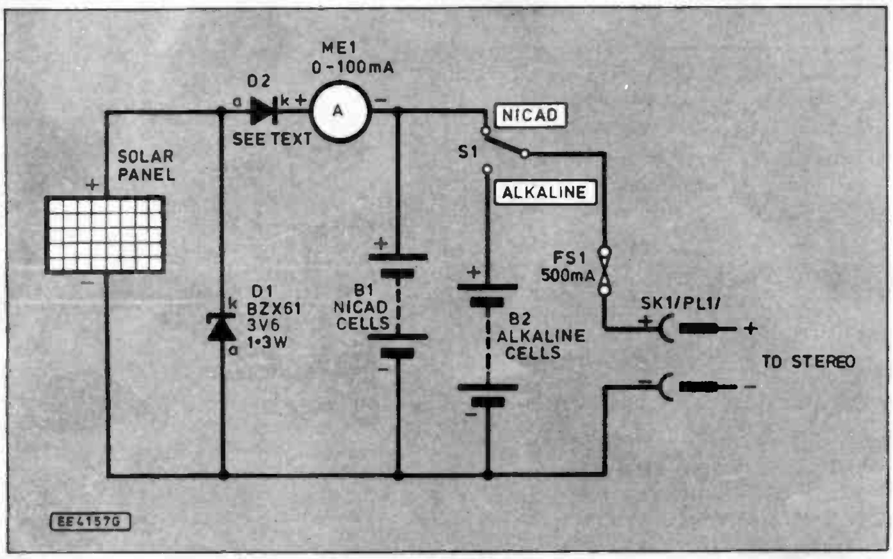


Fig. 1. Circuit diagram for the Solar Personal Stereo Supply.

Before ordering components, it would be a good idea to confirm that the stereo unit will work from two nickel-cadmium cells – that is, from a 2·4V supply. The nominal output of this type of cell is only 1·2V rather than the 1·5V of a standard alkaline one. However, in use, the terminal voltage of a conventional cell will fall to some 1·2V or less before it needs to be discarded. This means that, in practice, the stereo will have been designed to work down to a much lower voltage.

Tests were carried out using three different stereos and all worked correctly down to 2·0V. Below this, the speed suddenly falls and the music becomes impossible to listen to. Check operation using two "AA" size nickel-cadmium cells (which could perhaps be borrowed and charged using a conventional charger). If the unit operates satisfactorily, then it will work with this circuit.

OVER-RATED

Two types of solar cell array were tested in this system. Both were found suitable and gave good results but there are advantages and disadvantages with each. The first panel was made using ten individual solar cells described as having a 0·45V 200mA output. This made a panel 18cm × 11cm approximately. The second trial used two *amorphous silicon* panels described as 1·87V 153mA solar cells (see *Shop Talk*). These made an array 10 cm x 12 cm.

The amorphous panels gave better overall performance and these were chosen for the final prototype unit. They are also much cheaper (a total of £8 compared with £15 for the individual ones.) Also, wiring-up the amorphous cells involves very little work, whereas interconnecting the individual ones is time consuming. However, the individual cells are much more robust and appear to be weatherproof (although this has not been tested).

By contrast, the amorphous panels are formed on a glass substrate which is easily broken. If the user needs a unit to attach to a back-pack while jogging or walking then obviously the individual cells will be necessary or in any case where the amorphous type could be broken. It is really a case of "you pays your money and you takes your choice."

Whichever type of solar cell is used, the current output rating must not be taken too seriously. This is stated under *ideal* conditions. Also, in this type of circuit, the maximum output current will not be realized anyway.

CIRCUIT DESCRIPTION

The circuit for the Solar Personal Stereo Supply is shown in Fig. 1. Diode D2, prevents current flowing back through the solar cells from the back-up batteries when the solar panel output voltage is low – i.e. in dim light. An ordinary silicon diode could be used here but it would introduce a voltage drop of 0·7V approximately and this is rather a lot in a circuit where "every little counts". The specified Schottky barrier diode is a little more expensive and is not stocked by all suppliers. On the other hand, it has the advantage of introducing a lower voltage drop, resulting in a slightly higher output current.

From diode, D2, current flows via milliammeter, ME1, to the Ni-Cad battery pack and to the Ni-Cad/Alkaline selector switch, S1. When Ni-Cad (N) is selected, current can flow via fuse, FS1, to the output socket, SK1, from the solar panel and/or the nickel-cadmium cells. If Alkaline (A) is selected, the solar cells still charge the nickel-cadmium pack but current for the stereo is now provided by the conventional cells.

If the alkaline reserve battery supply is not needed, it can be omitted together with the selector switch. Fuse FS1 is then connected direct to the Ni-Cad battery positive terminal. If the meter is not fitted, it is simply by-passed.

COMPONENTS

Semiconductors

D1 BZX61 3·6V 1·3W Zener diode
D2 1A Schottky barrier diode (or 1N4001 silicon diode) – see text

See SHOP TALK Page

Miscellaneous

PL1/SK1 2·1mm power type plug and matching chassis socket
PL2 1·3mm power type plug (or to suit stereo set)
B1 "C" size 1600mAh nickel-cadmium cells (2 off)
B2 "C" size alkaline cells (2 off) if required. See text
ME1 Milliammeter with 100mA f.s.d. (see text) face size 46 x 60mm approx
FS1 500mA 20mm fuse and chassis fuseholder
S1 Miniature s.p.d.t. rocker or toggle switch

Solar panel: either 2 off 1·87V 153mA amorphous silicon solar panels or 10 off G200 0·45V 200mA solar cells – see text

Sloping-front case size, 215mm x 130mm x 78mm (max height) 47mm (min height) or as required – see text; cell holders for two "C" size batteries (2 off or 1 off if B2 is not used); tag strip – 3 tags required; light-duty twin wire; stranded wire; dummy AA cells (if required) solder, etc.

Approx cost guidance only

£20 to £31

see text

VOLTAGE REGULATION

Voltage regulation is provided chiefly by the Ni-Cad batteries themselves. Solar cells have a high internal resistance – that is, the resistance of the material used in their construction. However, the resistance of nickel-cadmium cells is very low. The effect of this is that the output voltage "locks" to that of the back-up cells and will remain so even when these are fully charged.

Should the back-up supply become disconnected for any reason while the solar panel is in bright sunlight, it would be possible for the voltage at SK1 to rise above 4V. To prevent any possible damage, Zener diode D1, having a breakdown voltage of 3·6V, prevents the voltage output rising to much more than 3V (this takes into account the voltage drop across diode D2). A Zener diode is always used in conjunction with a series resistor but here this resistor is the internal resistance of the solar cells themselves.

Fuse, FS1, is included because nickel-cadmium batteries can deliver very high currents and hence cause damage when short-circuited. This could happen by accident if the connections touched inside one of the connecting plugs, for example.

The milliammeter used in the prototype unit was scaled 0 to 100mA and this was found to be sufficient. If the full scale deflection is ever exceeded it will not cause damage. However, if a meter having a full-scale deflection of 200mA or 250mA is available this could be used instead.

It would also be possible to use a shunt resistor (a resistor connected directly across the meter terminals) to increase the full-scale deflection. The resistance of a typical 0 to 100mA meter is 0·8 ohm. By using a shunt of the same value (two 1·5 ohm resistors connected in parallel would do), the meter would read up to 200mA.

CONSTRUCTION

In the prototype unit, everything was mounted on the lid of the box since this method simplifies construction and minimises strain on the connecting wires (Fig. 2). Begin by drilling holes for the solar cell wires to pass through. Drill holes also for battery holders, tag strip, fuseholder and output socket mounting. Make a hole for the switch and the meter (if used).

To make the meter hole, drill a circle of small holes and join these together using a hacksaw blade. The edge may then be filed smooth. Mount these components noting that it is the centre tag (tag 2) which secures the tag strip to the metal lid.

Refer to Fig. 2 and solder the two diodes into position on the tag strip as indicated taking care over their polarity. Remember, D1 is a Zener diode and, as such, is used in reverse bias with the band on the body (cathode, k, end) connected to the *positive* of the supply – i.e. tag 3.

Pass the solar cell connecting wires through the holes drilled for the purpose. Sleeve them at the point of entry – or use rubber grommets – to prevent the possibility of them being cut by the rough edge of the hole and mount the panels using ten adhesive fixing pads (one in each corner and one in the centre of each).

If individual cells are being used, they will need to be mounted on a thin plastic or hardboard insulating panel which will replace the existing aluminium one. They are then connected in series as shown in Fig. 3.

Refer again to Fig. 2 and complete the interwiring. When using amorphous panels, these are connected in series as shown in Fig. 4. Note the connection between the positive wire of one solar panel and the negative of the other one. This is sleeved to prevent short-circuits. Note also that tag 2 must be wired to the terminal of SK1 which is connected to the metal body (if applicable).

Take care when soldering to tag 2 since this is a meeting place for several wires. If the meter is not used, it is by-passed. If the alkaline batteries and changeover switch are not included, the wire leading from tag 1 (via the meter if used) is connected to FS1. The positive connection from the nickel-cadmium battery pack is connected to FS1 also. The switch is labelled N (nickel-cadmium) and A (alkaline). It does not matter in which sense the outer connections are made but the common (centre) one must be connected to the fuseholder.

CONNECTION

Make up the personal stereo connecting lead. This may be of any reasonable length. Use light-duty stranded twin wire with a 1·3mm plug soldered to one end (or as appropriate to the socket on the stereo unit) and a 2·1mm plug on the other. It is essential to observe the polarity of the personal stereo so check this point carefully – there is often a diagram inscribed on the plastic body next to the socket.

If there is no such d.c. connecting socket, it will be necessary to use a pair of "AA" size dummy batteries instead. Their real use is as shorting links – they therefore have their ends interconnected. The first job is to cut through the link wire and remove a section (see photograph). Wires are then soldered to the positive connection of one and the negative of the other. The pair of

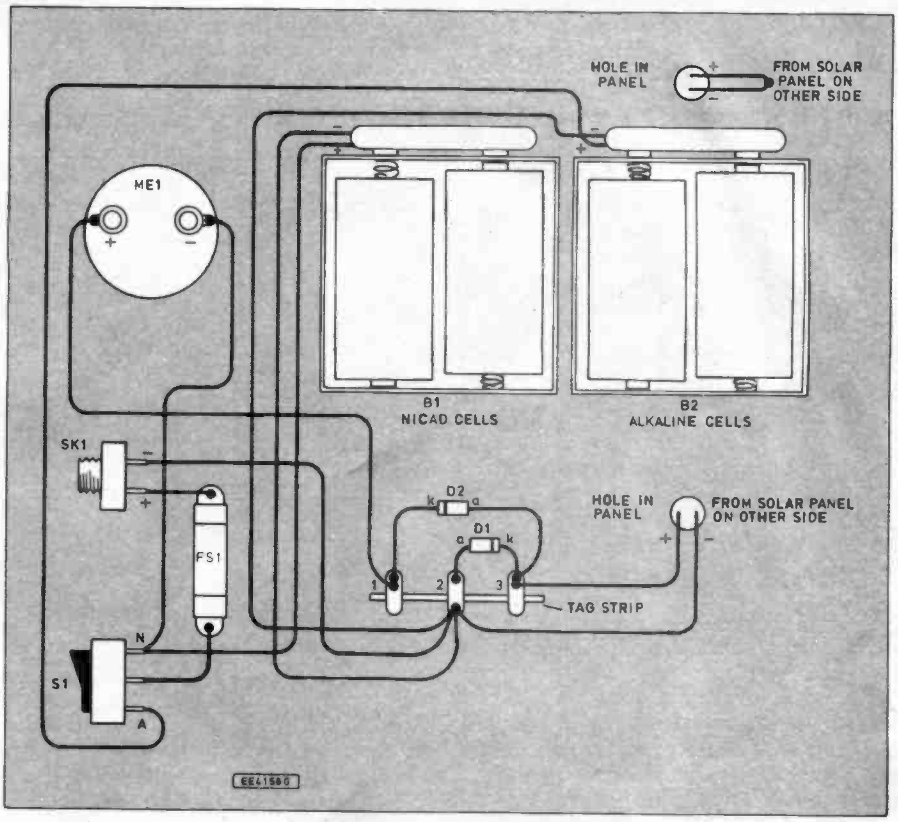
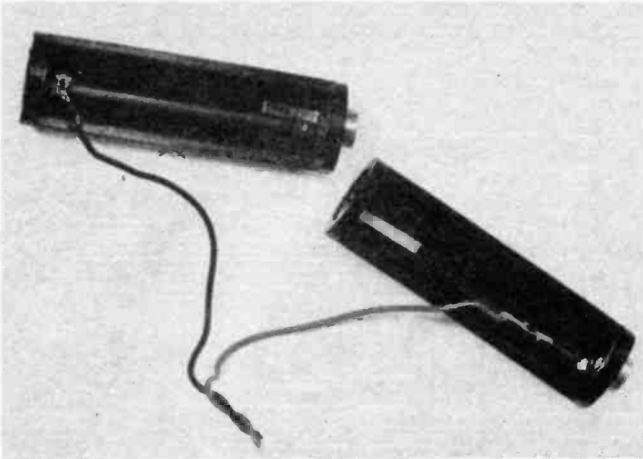


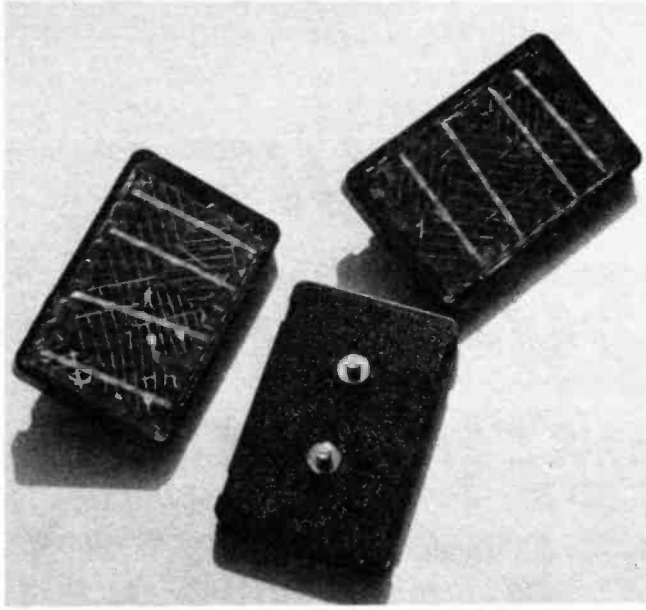
Fig. 2. Interwiring between components. Tag 2 is also used for bolting the strip on the metal panel.

Layout of components on the rear of the metal "lid" of the case.



Making up two dummy "cells" for units without d.c. sockets.

"cells" may then be inserted into the battery compartment in the same way as conventional ones. It will be necessary to carefully file a small piece off the corner of the battery cover to allow the wire to pass through.



(above right) Individual solar cells.

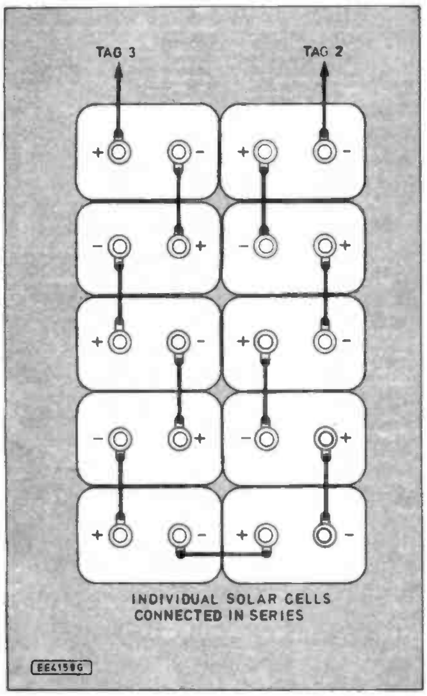


Fig. 3. Wiring individual cells in series.

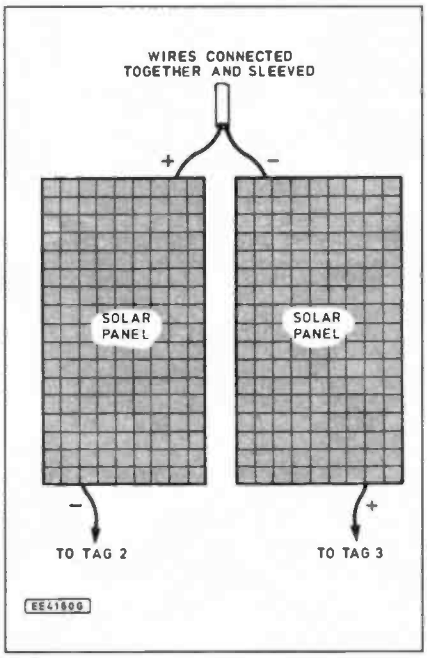


Fig. 4. Method of wiring amorphous panels in series.

TESTING AND OPERATION

If a multitester is being used for testing purposes, set this to milliamps d.c. If a meter is not available, then operation will simply have to be taken on trust. Note that the "Walkman" does not need to be connected during this test.

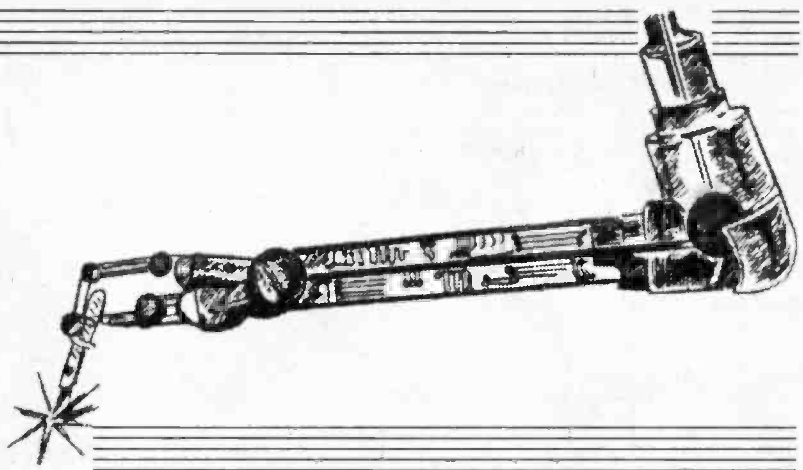
Disconnect the connecting wire from tag 1 for the moment. Connect the positive multitester probe to tag 1 and the negative one to the free wire. Check the charging current with bright light shining on the solar panel. This could be 100mA or so in direct sunlight.

If no current is indicated and the light is bright enough, suspect a wiring error or that one of the diodes has been connected the wrong way round in the circuit. If all is well and with testing complete, re-connect the wire to tag 1. The unit may then be put on a period of trial.

The switch could be labelled *Alkaline* and *Nickel-Cadmium*. However, whether or not using labels, make sure you know which switch position is which – if necessary, remove one of the cells to check whether or not the stereo works on that setting.

You will always be "wired for sound" with the Solar Personal Stereo Supply, let's hope it is a sunny summer! □

CIRCUIT SURGERY



MIKE TOOLEY B.A.

Welcome to* Circuit Surgery, *our regular clinic which deals with readers' problems. This month's Surgery will be of particular interest to radio enthusiasts as it contains a number of simple but useful circuits which can be used for aligning and calibrating receivers and testing aerials.

Crystal maze

Steve Mason asks:

"How is it that a quartz crystal can have two resonant frequencies when ordinary tuned circuits only have one?"

In order to understand this, Steve, you need to be aware of the *equivalent circuit* of a quartz crystal (see Fig. 1). At first sight this circuit may look a little complex however it is important to realise that the crystal exhibits both series and parallel capacitance.

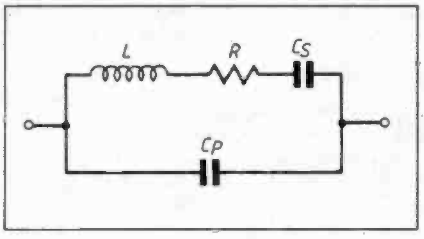


Fig. 1. Equivalent circuit for a quartz crystal.

The result is that the component can be regarded as either a series tuned circuit (L and C_s in series) or as a parallel tuned circuit (L in parallel with the effective series capacitance of C_s and C_p). The mode of operation (i.e. either series or parallel) will be dictated by the external circuitry. The impedance-frequency characteristic for a typical quartz crystal is shown in Fig. 2 (note the series and parallel resonant points).

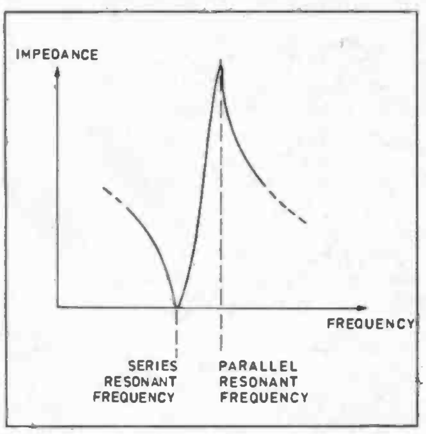


Fig. 2. Impedance-frequency characteristic for a quartz crystal.

Crystal oscillator circuits are designed either to promote oscillation with the crystal operating in series mode (in which case the crystal will exhibit a very low impedance) or in parallel mode (in which case the crystal will exhibit a very high impedance). The manufacturer will suggest which mode is recommended for a particular crystal depending upon the method of construction and type of "cut".

Happily there is, in fact, little difference in the series and parallel resonant frequency of a crystal (only a few hundred Hertz for a typical medium frequency crystal). Furthermore, this difference can usually be "trimmed out" by means of series or parallel capacitance (a trimmer of 50pF, or so, will normally be perfectly adequate).

Whilst on the subject of quartz crystals, it is worth mentioning that these components can be used as the basis of a very accurate signal source for calibrating radio receivers or r.f. test equipment. This rather neatly brings me to a letter from short-wave enthusiast, ***Martin Holmes:***

"I need a means of calibrating the scale of an ex-military h.f. receiver. Can this be done using only one crystal or will I need several (e.g. 1MHz, 2MHz, etc)"

Fortunately, Martin only needs one (reasonably accurate) crystal. The other frequencies that he requires can simply be harmonic "markers" derived from the same source (e.g. a 1MHz source will produce harmonics at 2MHz, 3MHz, 4MHz, and so on).

A reliable crystal calibrator circuit which I have used over the frequency range 100kHz to 10MHz, with component value changes indicated in Table 1, is shown in Fig. 3. An alternative oscillator circuit (for low-frequency crystals) is shown in Fig. 4. This circuit is recommended for use below 4MHz.

Crystals for use in calibrator circuits can be purchased from a number of component suppliers. As an example, Maplin can supply crystals at 1MHz, 2MHz, 2·5MHz, 5MHz and 10MHz (though it is worth noting that crystals designed for "microprocessor use" are significantly cheaper than those designed for use as "frequency standards").

The signals produced by the circuits

Table 1

Resistor	Frequency range 100kHz-2MHz	2MHz-10MHz
R2	2k2	4k7
R3	4k7	1k
R4	470	220

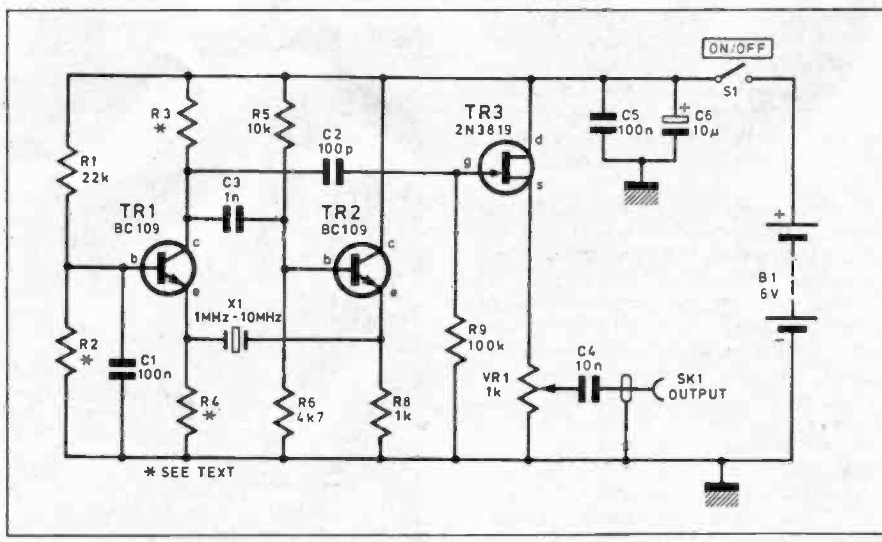


Fig. 3. General purpose crystal oscillator circuit. Values for components marked with an asterisk are given in Table 1.

shown in Figs. 3 and 4 are reasonably pure and, although harmonics may be present at low levels, they may be too small to provide "markers" for calibrating receivers over the full h.f. spectrum. In such cases, a simple squaring circuit (see Fig. 5) can be used. This circuit produces a signal which is rich in harmonics (harmonics of a 100kHz input signal will be detected at well over 30MHz on an "average" h.f. receiver!).

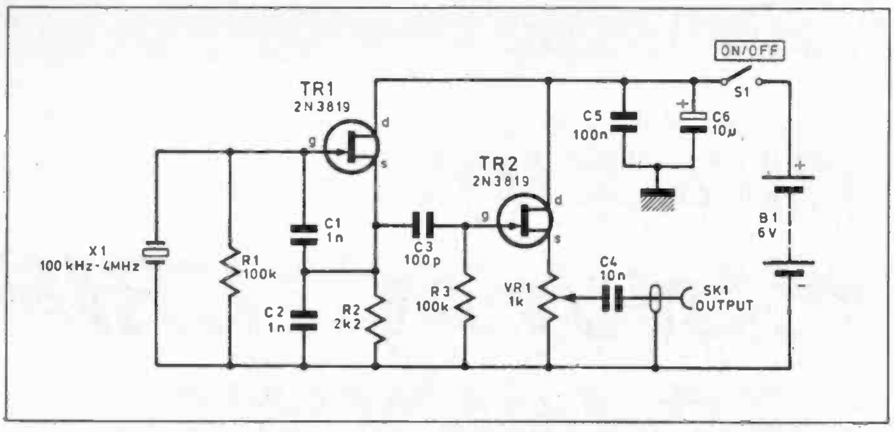


Fig. 4. Low-frequency crystal oscillator.

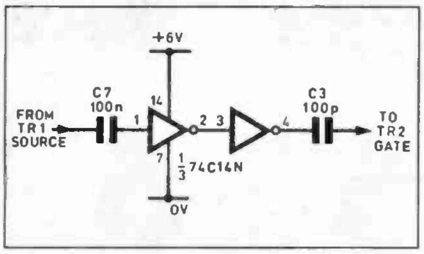


Fig. 5. Harmonic generator circuit.

Simple R.F. Noise Bridge

I recently overheard a conversation between two "Novice" radio amateurs. The main topic of the conversation was how it was that a coaxial cable which appeared to have infinite resistance when measured with an ohmmeter could have an impedance of 50 ohm.

One Novice had used his digital multimeter to carry out resistance measurements on two aerials. He was greatly surprised to find that one antenna measured virtually short-circuit whilst the other appeared to be open-circuit even though both aerials seemed to work quite well!

The reason for this apparent anomaly, of course, is simply that d.c. measurements of resistance bear little relationship to the impedance measured at radio frequency. To put the record straight, the rated impedance of a coaxial cable (often 50 or 75 ohm) is the impedance which would be "seen" if one was to "look" into an infinite length of the cable. The impedance is directly proportional to the square root of the ratio of inductance to capacitance.

Most coaxial cables designed for radio frequency use have an impedance of either 50 ohm or 75 ohm (the latter is commonly used for TV and f.m. radio aerial feeders). Better quality cables tend to have lower loss and higher power handling capacity.

In order to minimise power loss and preserve a near-unity voltage standing wave ratio (VSWR), aerials and their feeders are usually "matched" (note that the impedance of an aerial depends upon how it is connected to the feeder). Aerials for communications and amateur radio applications are generally designed for use with a 50 ohm feeder (the impedance seen "looking into" the aerial is thus 50 ohm, regardless of the length of the feeder cable).

When I later met the two Novice operators, I suggested that they might like to check the impedance of their aerials using the simple "Noise Bridge" shown in Fig. 6. This simple yet effective circuit can be used to provide a rapid check of r.f. impedances between five ohms and 1·5 kilohms (in two ranges). The circuit operates reliably over the frequency range 150kHz to 150MHz but care should be exercised in its construction if v.h.f. performance is to be maintained.

The noise bridge is excited by means of a wideband square-wave source (IC1a to IC1c). This simple arrangement provides anti-phase outputs at a p.r.f. of about 1kHz which will appear as a "broadband" signal when connected to a receiver. To simplify operation, VR1 should be fitted with a pointer knob and a large scale that can be calibrated using a handful of (known) carbon resistors (e.g. 10 ohm, 33 ohm, 47 ohm, 56 ohm, 68 ohm, etc).

The receiver (used as a "null detector") should be connected to SK2 by means of a *short* length of matched (50 ohm) coaxial cable whilst the aerial on-test should be connected to SK1 via a length of matched coaxial feeder cable (note that the outer screen connections of SK1 and SK2 are "commoned"). VR1 should be adjusted (with S2 set in both range positions) until a null is detected (this should be quite sharp). The aerial impedance can then be read from the scale fitted to VR1.

It is important to note that the receiver should be an a.m. or s.s.b. type as f.m. receivers are *not* suitable for use in this application *unless* fitted with a signal-strength meter. If the receiver has a switchable automatic gain control (a.v.c. or a.g.c.) this should be switched off and the manual r.f. gain control adjusted to produce a satisfactory audio level or signal-strength indication.

Next month: We return to the low-frequency world with some useful information for would-be digital designers. 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.

COMPONENTS

R.F. Noise Bridge

Resistors

R1	1k
R2	560
R3	100
R4	1k

All 0·25W 5%

Potentiometer

VR1	1k carbon lin.

Capacitors

C1	1µ axial elect. 63V
C2	10µ radial elect. 16V
C3	100n polyester
C4, C5	100p polystyrene (2 off)

Semiconductors

IC1	74LS14 Hex Schmitt trigger inverter

Miscellaneous

SK1, SK2	50 ohm panel mounting BNC socket (2 off)
S1, S2	SPST miniature toggle switch (2 off)

Battery holder (to accept 4 x 1·5V AA-cells); Large pointer knob; 14-pin low-profile d.i.l. socket; Small metal or ABS enclosure (approx. 118mm x 98mm x 45mm); Small piece of matrix board (approx. 100mm x 70mm); Terminal pins (4 required).

Approx cost guidance only **£10**

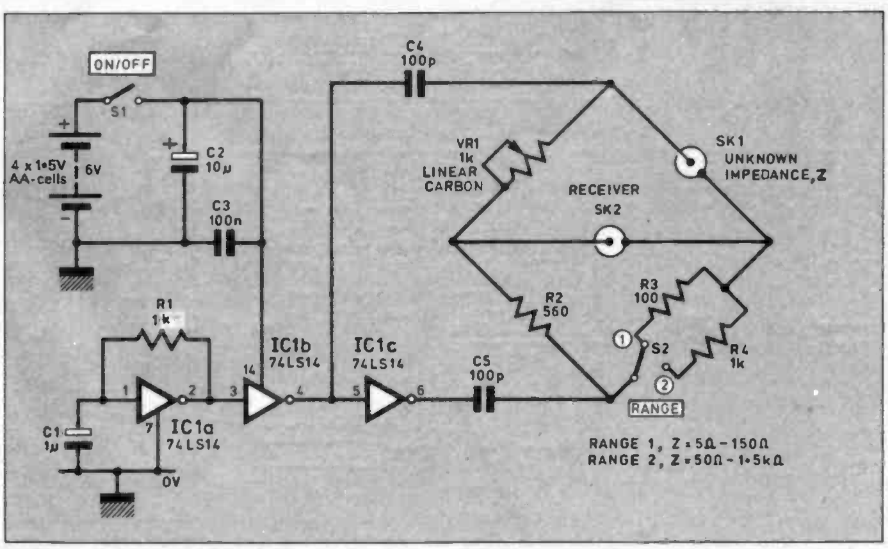
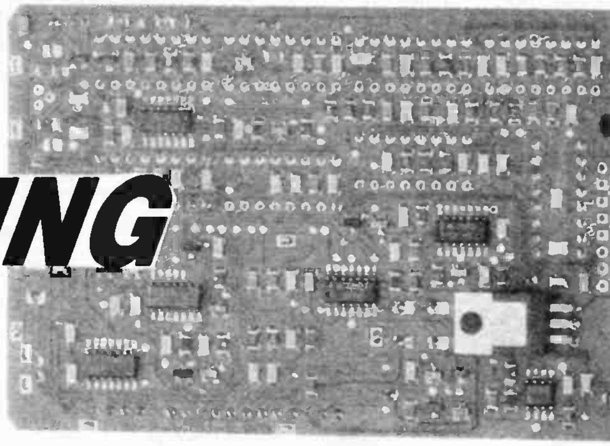


Fig. 6. Complete circuit of the R.F. Noise Bridge.

Special Feature

MODERN MANUFACTURING TECHNIQUES



IAN POOLE

We investigate one of the most important developments ever in the electronics industry. Surface mount technology has many advantages

Look into any piece of consumer electronics equipment today and it is packed full of minute electronics devices. Electronics has come a long way since the days of the first transistors and today's equipment demonstrates it. To achieve this, manufacturing techniques have also progressed a long way.

Producing any equipment economically these days means that very high levels of automation are needed. Labour costs are far too high, and the equipment is much too complicated for hand assembly techniques to be used for all but a very few specialised components.

COMPONENTS

One of the keys to the success of today's mass production techniques is surface mount technology (S.M.T.). Along with this a whole new range of devices has been introduced. These surface mount devices or S.M.D.s were first introduced in the early 1980s. Initially only few manufacturers used them. Now most volume production throughout the world uses them, and conventional components are being used less.

The new technology was developed because it was found that conventional components were not easy to place and insert into the boards automatically. A very high degree of accuracy was needed to be able to accomplish this. First of all the leads had to be accurately spaced. I.C.s for example had to have their leads bent slightly to ensure the correct spacing across the body of the chip.

Passive components like resistors had to have their leads pre-formed or bent round so that they would fit. All of this was time consuming and costly. In addition to this the automatic machines were continually stopping because components were difficult to handle and fit.

These difficulties meant that many operations had to be performed by hand. This added large amounts to the cost of a product. It is normally recognised that labour is one of the largest costs in any product.

AUTOMATIC

To overcome these problems surface mount devices were introduced. As the name implies the components are not mounted through holes in the board. Instead they are placed directly onto the surface of the board, where there are suitably placed copper pads for the connections, then soldered in place. Because these components do not need leads to be fed through holes in the board they are much easier to place onto the board automatically.

As a result of this revolution a whole new range of components has been developed. Everything from resistors and capacitors through to the most complicated i.c.s are now all available in surface mount formats. In fact some of the new and highly specialised i.c.s are now not being introduced in the conventional formats.

CAPACITORS

Passive devices like resistors and capacitors are some of the simplest devices. They consist simply of the basic component itself with no leads. Instead at either ends there are metallised areas which act as the contact for soldering.

Most of the capacitors which are used are ceramic types. Their internal construction is very similar to the conventional leaded types. There are alternate layers of dielectric and plates as shown in Fig. 1.

The end cap is of particular importance. In early types the cap was made of silver palladium. This was not easy to solder as the metallisation could be "leached" away by the solder if the heat was kept on for too long. This would destroy the conductivity of the connection, rendering the component useless. To overcome this problem a nickel barrier was added into the cap as shown. This greatly reduced the problem, although it is still not advisable to leave the device heated for too long.

These ceramic devices are available in a very wide range of values from as little as 1p right up to around 0µ5. For larger values tantalum types are generally used. Aluminium electrolytics are seldom seen because they do not withstand the high temperatures which can be applied directly to the components.

RESISTORS

Resistors look reasonably similar to the capacitors although it is easy to distinguish between them. They are constructed using thick film technology. A resistive paste is placed onto a ceramic base. This is protected by a glass layer. Finally a conductive cap is applied. Fortunately these caps are much less prone to the leaching problem than the capacitors, even the nickel barrier ones.

The resistors and capacitors are available in various standard sizes. Numbers like 1206, 0805 etc are some examples of the codes used to describe the package size. Fortunately these figures have a meaning. The first two digits indicate the nominal length in hundreds of an inch and the second two give its width.

The 1206 size (3·2 × 1·6mm) was the most common for resistors a few years ago,

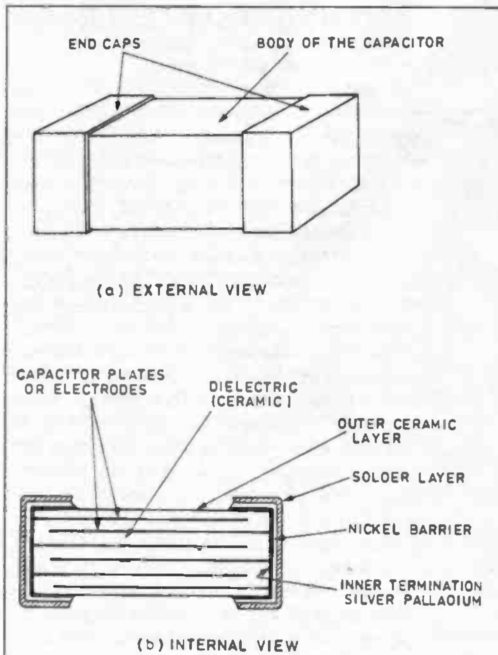


Fig. 1. Construction of a surface mount capacitor.

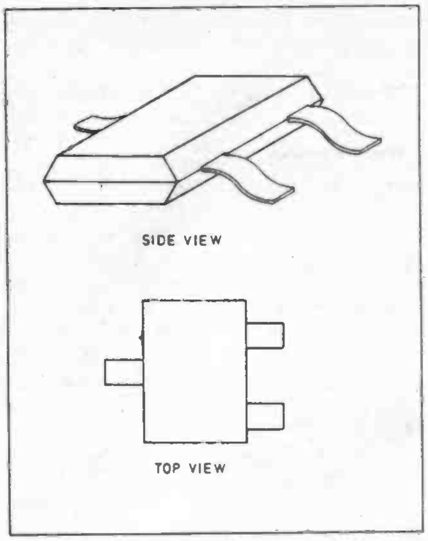


Fig. 2. A typical surface mount transistor or diode.

but now 0805 components (2·0 × 1·25mm) are more widely used. However, even smaller components with an 0603 package (1·6 × 0·8mm) are now available and it is very likely these will become the standard in the years to come.

MARKINGS

One of the problems which arises out of the size and construction of these components is the way in which they are marked. Capacitors are not marked at all! If they are left loose on the bench then the only way to identify them is to measure their value with a capacitance meter. Normally this is not too much of a problem if they are kept in their packaging until they are needed.

Fortunately most surface mount resistors do have their values marked, even though the print is very small. Actual figures are used although the same system as used with ordinary resistors is employed, i.e. the two first figures represent the significant figures and the third gives the multiplier. Thus a resistor marked 472 would have a value of 4k7.

TRANSISTORS AND DIODES

Semiconductors have not been immune from this revolution. New packages have appeared for transistors and diodes and like their passive counterparts the new surface mount components are much smaller than the older conventional ones.

For most general purpose transistors and diodes a package style known as a SO23 has been adopted. This is possibly the equivalent of the TO18 can for conventional transistors. However, the surface mount package is very much smaller measuring only 3 × 1·4 × 1mm.

Unlike capacitors and resistors where an area of metallisation on the edge of the package is used for the connections, these devices actually have wires. As shown in Fig. 2 the leads are bent so that they lay flat onto the surface of the board.

Diodes also use this package. Whilst the third lead is not used as a connection it serves to indicate the polarity of the device. This is vital because the packages are so small that any marking like the ring showing the cathode of a conventional diode would not be easily visible.

The SO23 package is the most common one for transistors and diodes, but it is not

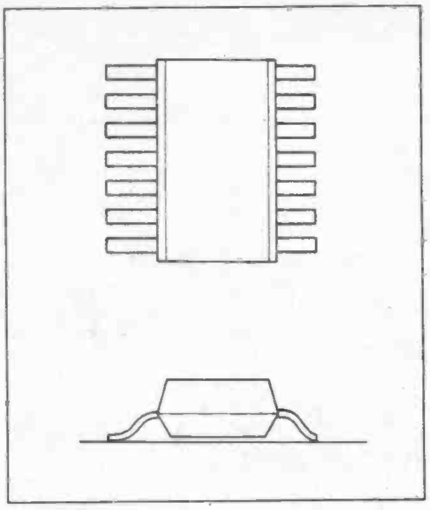


Fig. 3. A gull-wing i.c. package.

the only one. Other packages are widely used for more specialised devices or those which need to dissipate significant amounts of power. As an example the SOT223 package style is able to handle dissipations of up to two watts.

INTEGRATED CIRCUITS

Integrated circuits (i.c.s) have their own set of new packages. There are two major styles which have developed and they are characterised by the type of leads they have.

The first type is known as a "gull-wing" as shown in Fig. 3. The package has leads very similar to the transistors and diodes and the name is derived from the similarity of the leads to a gull's wing. All the popular ranges of logic i.c.s are available in this form.

The actual outline of the body of the i.c. is very similar to that of the conventional equivalents, but somewhat smaller. Even the pin spacing is reduced. On the more common i.c.s it is reduced from 0·1 inches used for conventional styles to 0·05 inches.

Some of the more complex i.c.s have leads on all sides as shown in Fig. 4. These packages known as "quad flat-packs" can often have more than 200 leads, and with this number of connections the pin spacing

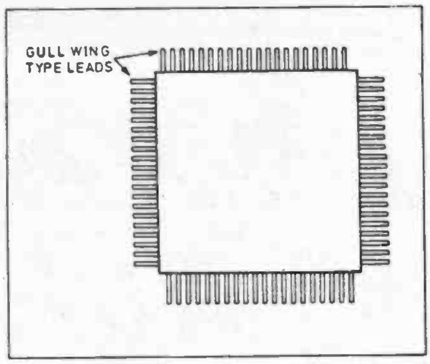


Fig. 4. Top view of a quad flat-pack i.c.

has to be reduced. Typically the spacing may be as little as 0.02 inches (20 thou). This means that the leads are very fragile and the i.c.s have to be handled with care. If the leads get bent they are not easy to straighten out properly.

The other style of package has a "J" lead. As one might imagine from the description the leads are in the form of a "J" as shown in Fig. 5.

For general applications gull wing devices seem to be preferred by manufacturers. The joints are more visible. Also the soldered joints can be made more easily and reliably, and rework is easier when an i.c. needs to be replaced. However "J" lead devices take up less board space, and this can be a great advantage when board space is at a premium. In addition to this they can be used in conjunction with a socket. This is a very valuable attribute when systems are being developed.

Initially the device which might be an EPROM can be placed in a socket. When full production is reached and the design and software are stable the device can be

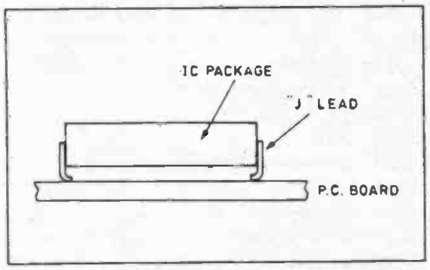
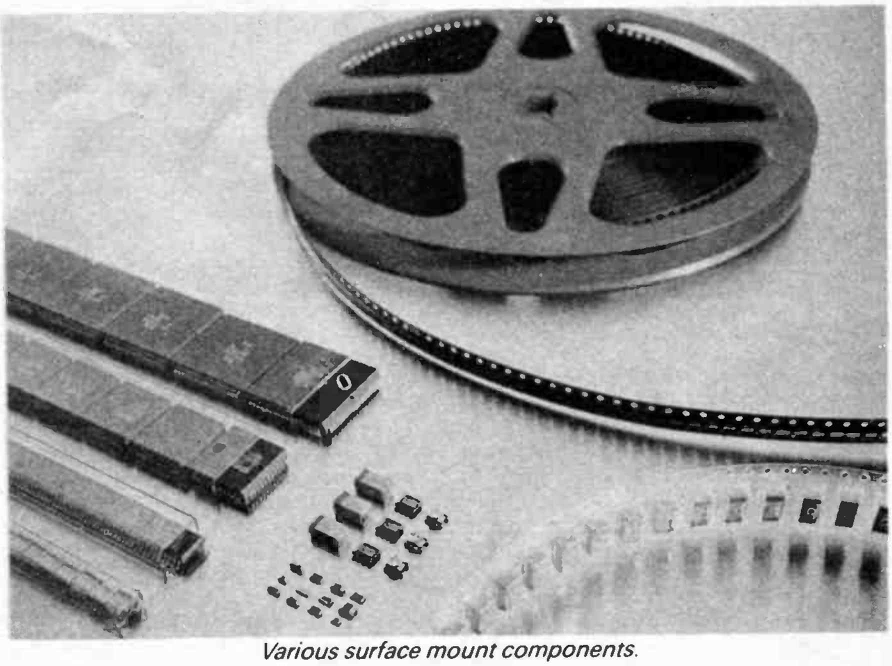


Fig. 5. A "J" lead i.c. package



Various surface mount components.

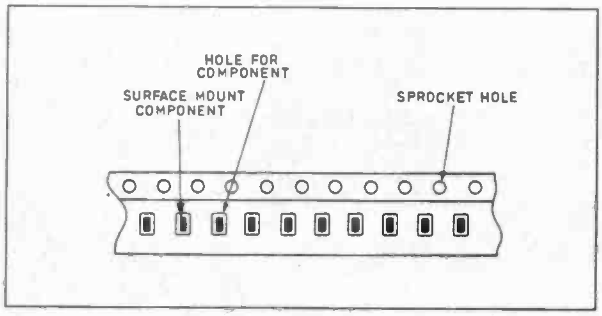


Fig. 6. A component tape, a plastic film covers the component and is removed as they are required for placement by the pick and place machine.

soldered directly to the board with no layout modifications.

Apart from the components which have already been described, most types of component are now available in surface mount packages. Everything from chokes, coils and coil formers to crystals and switches. These components are generally smaller than their conventional counterparts enabling circuits to be made even smaller and have far more functionality packed into the same space.

PLACING THE COMPONENTS

To place the components onto the printed circuit boards very sophisticated "pick and place" machines are used. These machines can be very expensive in view of their complexity, often costing upwards of £100,000. They pick the individual components up and place them down on the board in the correct place and with the correct orientation.

To enable the machines to operate the components have to be held in special packing. They cannot be held loose like normal components because the machine would not be able to handle them.

Small components like resistors and capacitors are supplied in what is called a tape and reel format. The reels holding these components come in a variety of sizes. Generally they are either 7 or 13 inches in diameter and a quarter of an inch wide. Larger widths are often used when larger components are needed, although the maximum width is normally around three quarters of an inch.

This tape can be either plastic or card and has an indentation or hole for each component. To prevent the components falling out of the tape there is a thin transparent retaining tape placed over the top as shown in Fig. 6.

I.C.s are also sold in the tape and reel format. However the minimum quantity it is possible to buy like this is usually 1,000 and this may be too great for many lower volume applications. In cases like these it is possible to use components in tubes.

Whilst pick and place machines can handle tubes without any problem, they hold far fewer components and will need changing more often. This means that the pick and place machines will stop for re-loading more often and this will reduce their efficiency. In view of this tubes are not used for high volume items.

The reels and tapes are mounted into special feeders before they are placed onto the pick and place machine. These feeders can be slotted into place on the machine quite easily. In addition it is also an easy job to remove them or exchange them for another one if necessary.

Apart from enabling the components to be mounted onto the machine the feeder also prepares the component so that it can be easily picked up by the machine. In the case of a tape the feeder accurately moves along as each component is removed, by means of a sprocketed wheel which engages with holes in the side of the tape. It also pulls off the protective cover revealing the next component.

For i.c.s or components which use tubes the feeder assembly is somewhat different. A "ski" slope type of feeder is used. In this the tube is angled so that the i.c.s run down the tube. Only one i.c. is allowed out of the tube onto the feeder itself ready to be placed. When this i.c. has been removed the next one will appear.

BOARD LOCATION

As might be imagined the boards have to be loaded into the machine very accurately otherwise the components will be misaligned. To achieve this an accurately machined plate called a platen is used. This acts as an adaptor between the machine's conveyor system and the board itself.

The board is placed on the platen and accurately aligned using some precisely positioned locating pins which line up with some tooling holes in the board. In addition to aligning the board the platen which is generally flat also gives support to prevent any bowing or movement of the board whilst components are being placed.

Sometimes hollows have to be machined into the platen if components are already in place on the underside of the board. This occurs when components are mounted on both sides of the board – a situation that is happening more often these days because boards are becoming smaller and more complicated.

SOFTWARE

Once the components are all ready and the board is on its platen the component placement is ready to begin. To do this the machine uses a specially prepared programme which tells it exactly where to place each component and which way round to place it.

Originally programs were written manually, and could take several days for the more complicated boards. Fortunately if the board has been designed using a computer aided design system (CAD) it is possible to use the computer output to generate the program. This can reduce the time for placement program preparation to a few hours.

In order to operate these machines use a vacuum. The pick up head moves to the correct place to pick a component. Sucking up the component it then moves over to the board, possibly turning to get the orientation of the component correct. Having done this it places the component down on the board in the correct position.

This placement has to be very accurate. Looking inside any of today's PCs will reveal a plethora of i.c.s with very fine pitches. Some of them have leads spaced at intervals of 20 thou or sometimes even less. This means that today's machines have to cope with these tolerances or less if they are to be able to keep up with developments at the rate they are occurring.

Using such machines many hundreds of components can be placed each hour. This makes them much faster and more accurate than any human operator. Despite their large cost, they are the only cost effective way of placing components onto a board. Today's boards can easily have upwards of a thousand components on them. This would be a mammoth task if it had to be done all by hand.

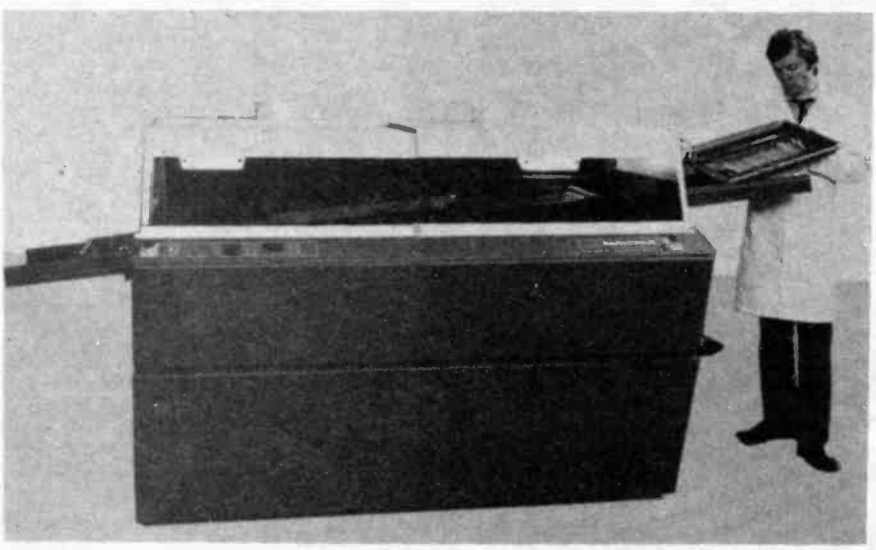
SOLDERING

Once all the components have been placed onto the board, the next stage is soldering. There are a number of ways of doing this, each has its own advantages.

One of the most established methods of soldering for mass production is called wave soldering. It is given this name because the board passes over a "wave" of solder.

The diagram of a typical wave soldering machine is shown in Fig. 7. The boards are first clipped into a conveyor to transport them through the various stages of the soldering process.

Once the board is clipped in place it is first passed over a wave of flux to ensure



A wave soldering machine.

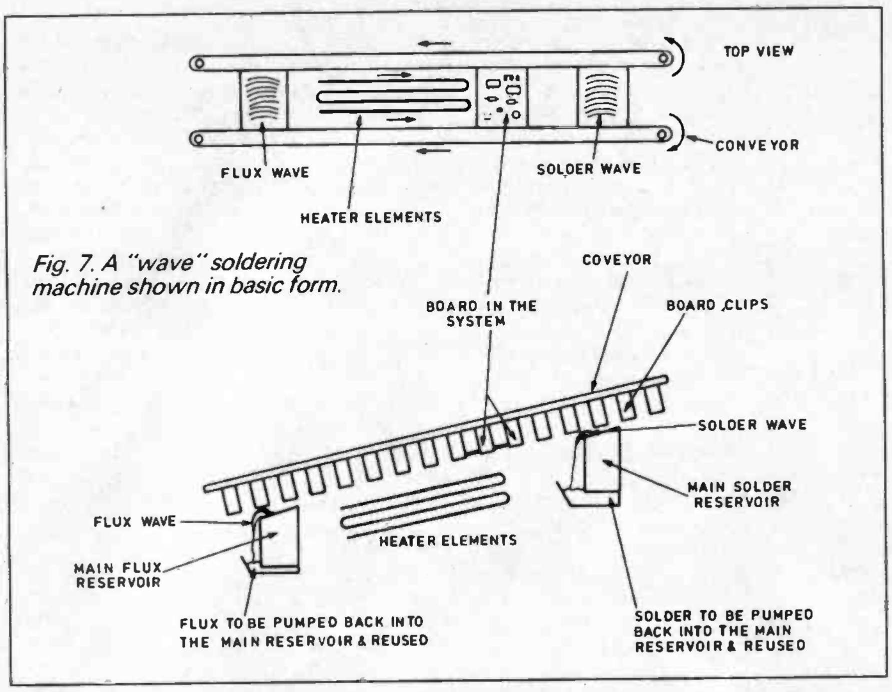
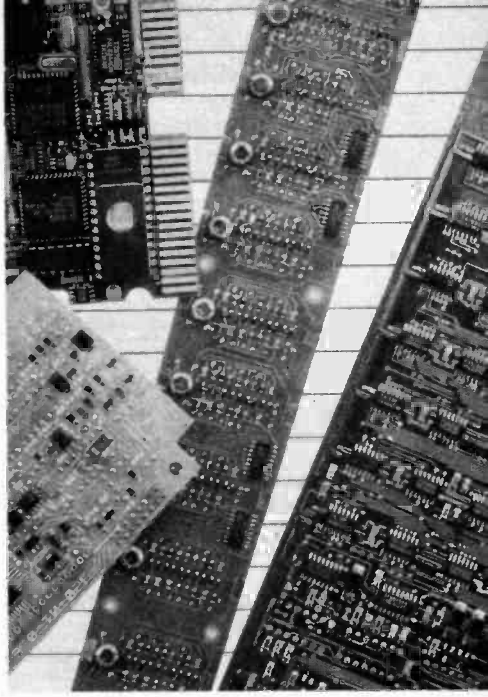


Fig. 7. A "wave" soldering machine shown in basic form.



Examples of S.M.T. boards.

it is properly cleaned. The wave is generated by ensuring that the flux flows over one edge of its container as shown in Fig. 7. The movement of the flux in this way ensures that the whole surface of the board is cleaned and excessive amounts are not retained on the board afterwards.

After cleaning, the board is passed over some heating elements. These are required to bring the components up to temperature steadily. In this way any thermal shock caused by the hot solder is minimised. This is particularly important for surface mount components which will be on the underside of the board and directly exposed to the molten solder. Conventional leaded components, however, are on the top surface and less vulnerable.

GLUED IN PLACE

For anyone wondering how the surface mount components stay on the board, they are usually fixed by a small spot of glue applied to the board by the pick and place machine before the component is put down. When all the components are placed the board is heated to cure the glue.

Once heated the board is ready for soldering. A wave of solder similar to the flux is used. For soldering conventional leaded components only a single wave is used. As the board moves along, the solder hits the underside of the board and the components are soldered in place.

For surface mounted components it is found that large components like i.c.s will tend to "shadow" some of the connections on the trailing side of the component. To reduce this effect the board is first passed over what is often called a "chip" wave. This wave is much higher and reduces the shadowing effect.

Whilst wave soldering has been used for many years and has been particularly successful for conventional components, it does have some drawbacks for surface mount components. In the first instance there is the shadowing already mentioned. This is overcome to a large degree by the chip wave.

Another problem with wave soldering is that there is a risk of solder bridges between pins, especially on the i.c.s with very small spacing between the pins. Fortunatley it is possible to reduce the problems. Simply adopting the correct standards for the p.c.b. layout greatly helps. I.C.s should be orientated the correct way round, and component pads should be a little larger than those required for other methods of soldering.

INFRA-RED REFLOW

Whilst wave soldering can be made to give reasonable results in many cases, other methods designed specifically for surface mount technology can give more reliable results. Of these a method known as infra-red reflow is becoming increasingly popular and is now used as standard by many manufacturers. As the name implies this method of soldering uses infra-red heating to heat the board and melt the solder.

When using this method it is necessary to use a solder paste. This is put onto the board prior to the component placement, and it is only needed on the component pads. To accomplish this a special screen is needed. This screen is placed onto the board and it allows solder paste to be forced through the screen only onto the required areas. In view of its nature a different screen is required for each different board. However if a large quantity of the boards are to be made the cost of the screen becomes very small.

Once the solder has been applied the surface mount components can be added in the normal way. In fact the solder paste has the added advantage that it helps keep the components in position after they have been placed. Whilst it does not hold them as firmly as glue, it is quite sufficient if the board is to be transferred straight to the solder machine.

The infra-red reflow machine has a conveyor belt passing through it. Boards are placed on the belt and then exposed to several stages of heating. By doing this the board can be brought up to the final temperature for soldering steadily without any thermal shock.

Generally there are three stages of preheating and then a final stage where the components are actually soldered. Careful setting up is required to ensure the correct temperature profile is attained.

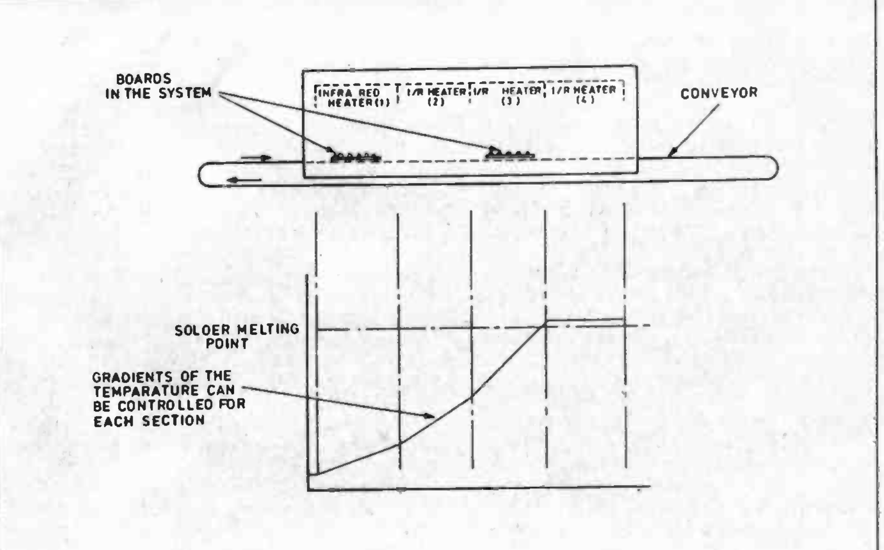


Fig. 8. Basis of an infra-red reflow soldering machine.

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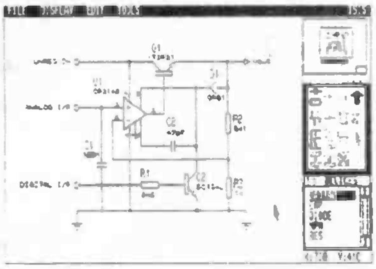

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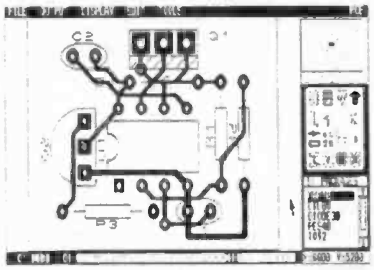

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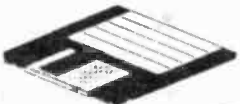

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BARCODE BATTLES BREAK-OUT

ALAN WINSTANLEY

Alan tries the very latest in mind teasing handheld games machines

Toy giants Tomy are set to enter the fiercely-contested handheld l.c.d. games market this summer with the U.K. launch of the "Barcode Battler" machine. Already a cult in Japan, the Barcode Battler (subtitled "Commerce Conflict") uses common-or-garden barcodes to boost players' points ratings. The unit has a built-in swipe card reader that is capable of reading ordinary barcodes found on groceries, magazines and other consumer goods.

WIZARD

Barcode Battler has a strategic theme of wizards and warriors, whose characteristics are programmed into the machine by scanning in various barcodes. Thus, players can increase their "energy", attack and defence ratings if they can find suitable barcodes which impart these much-prized qualities.

A pack of barcode cards is supplied, representing an assortment of characters, weapons and other game essentials. The unit requests various classes of card to be swiped, so that players can determine how they wish their characters to be "tweaked". It also calls for further card swipes during longer games. Battles consist of the computer setting off one player against the other, displaying hit points and damage based on the contestant's various strengths and weaknesses as derived from their barcodes.

NOODLE POWER

However it's possible to create one's own codes by Sellotaping suitable barcodes (snipped from some groceries, for example) onto blank swipe cards (supplied). Only by actually trying the barcode can you discover whether it has any points value. Apparently the sales of a particular brand of noodle suddenly rocketed in Japan, as players rushed to arm themselves with the ultimate barcode!

This market has so far been dominated in the U.K. by the Nintendo Game Boy and Sega's Game Gear colour machine. There has been widespread concern recently about the cost of the game cartridges, which can be anything from £25 upwards. Cartridges for TV consoles can typically cost £40 to £65 – games recorded on compact disc are looming round the corner with the introduction of the Sega Mega CD unit – and of course there's the inevitable peer pressure to buy the latest game chip.

FREE "SOFTWARE"

No such cartridges are needed for Barcode Battler. The "software" is in effect contained in freely-available barcodes, which takes the heat out of coughing up for the latest games cart. New codes mean new points ratings which can give a valuable advantage to the game player. Such barcodes themselves might form an electronic "conker", where one player's barcode is played off against another.

The display itself contains mainly digital information about each player's points ratings, and although the action shown on the l.c.d. display is a little limited, the player's imagination is left to run riot as the machine pitches one player against the opponent, with a repertoire of bleeping sound effects and flashing l.e.d.'s. It looks like healthy fun.

I managed to get hold of one of the pre-launch models. Barcode Battler is battery-operated and alkaline (or rechargeable) cells are recommended. There is no mains adaptor socket. It's possible to have either one or two player modes: in the former, you are pitted against the machine which picks the codes of any one of 120 "internal" opponents. There's also a Game Save mode so that long adventures can be played out.

TECHNOLOGY

The machine uses a flat-pack chip which is custom-made by NEC, and a liquid-crystal display that has tinted zones as a backdrop. Sound comes from an effective internal piezo transducer, although no earphone socket is fitted. Five small light-emitting diodes flash in sequence on the front to add interest and the numerical information is clearly visible on the l.c.d.

The barcode swipe unit is an infra-red reflective sensor mounted on another p.c.b. and barcodes are simply drawn through the slot and past the sensor. I had no problems at all with the scanning of barcodes, though sometimes the unit won't accept a barcode if it represents an "illegal" number; the only way to find out is to try it, which adds to the fun value. From experience I know that barcodes that are protected by a reflective transparent finish can be impossible to scan, but again there were no problems using sellotaped barcodes as the bars pass directly over the sensor. It seems a very reliable arrangement.

NEW TWIST

Barcode Battler undoubtedly adds a completely new twist to the hand-held l.c.d. games market. It doesn't fuel a demand for expensive games cartridges but instead the game-play relies on the players' imagination. Added to which, there is a limitless supply of software available in every supermarket, so the race will be on to find that certain product whose barcode yields indestructible magical powers!

It reaches Britain this month and will be keenly priced at £40 or so – the price of many console games cartridges alone. Expect it to be a hot contender for the number one slot at Christmas time. For further details and price information, contact the Tomy Customer Careline number 0703 876627. □

Next month we will take a look at barcodes in general and explain what they mean and how they are being used in a variety of ingenious ways.

SHOP TALK

with David Barrington

Micro Lab (Teach-In '93)

If you want to exploit the full potential of the *Micro Lab* it is most important that only the specified components are used throughout this exciting project. The Micro Lab is an ambitious project for more advanced readers rather than absolute beginners and will appeal to anyone wanting a versatile fully programmable design either for educational use or dedicated to a particular application.

To help constructors, we are pleased to announce that two companies have agreed to produce *complete* kits for the Micro Lab and are selling these for £149.95 per kit; which in view of the complexity of the project seems a very reasonable price. The two companies are: **Greenweld Electronic Components, 27D Park Road, Southampton, Hants SO1 3TB** and **Magenta Electronics, 135 Hunter Street, Burton-on-Trent, Staffs DE14 2ST.** Magenta also offer a built and tested version.

Anyone who can solder neatly should genuinely be able to tackle the project with a high probability of success. Some of the parts are specialised but the Authors have ensured that everything is available from the mainstream mail order suppliers. It is critical that the correct parts are used otherwise fault-finding – if necessary – may be nearly impossible, so consider the Parts List closely. Check before buying and you should have no problems at all, or better still why not purchase a complete kit.

Taking the Parts List in order: the 2k2 DIL Resistor array must be "8-individual" types, similar to the type used in the *Mini Lab* Digital Display. Ensure all capacitors are 5mm pitch to fit the board neatly.

The light-emitting diodes and 7-segment display should be low-current types. The 6502 is a cheap 1MHz type from RS (303-107). A faster version (e.g. 3MHz) will also work.

Both the specially-programmed EPROM and the PAL device are produced solely by Dytronics and are supplied with the Micro Lab p.c.b., from the *EPE PCB Service*. The Micro Lab User Manual" is also supplied with the board, and contains useful information.

The 256K SRAM (i.e. a 32kiloByte type) is readily available from many sources e.g. RS 265-465. Chip manufacturers have their own part numbers but they are all interchangeable.

The keyboard interface IC4 is unusual and not widely available. It's listed by Maplin (YH51F) and Cricklewood. The VIA chip IC12 is also an RS type, 631-424.

Part numbers for the connectors are: Con 1 Farnell 208-930, RS471-070, Maplin FJ16S; Con 3 RS334-555: SK1, Sk2 Farnell 208-747, RS471-238, Maplin FC86T. The keypad switches are Farnell types (176-435, 176-443, 262-432) and were amongst the cheapest available. The only other part to select with care is the liquid crystal display. Shop around! Greenweld list a cheap type (£6 plus P&P) which has been tested and approved by the Authors: type TLCM1621 (Greenweld Part No. Z5483D).

Other types may also fit: generally, the 14-way pin-outs of these types of l.c.d. are all compatible but it's the physical dimensions and layout which needs to be checked. Whilst dimensions may be the same, the pin-outs may be in a different position and may not align with the Micro Lab board.

Xenon Strobe

Some of the components listed for the *Xenon Stroboscope* may prove a little difficult to find locally, but it is essential that only new components be used in this project. Also, the *power* ratings of the resistors and the *voltage* (i.e. working voltage) ratings of the capacitors *must NOT be less* than specified.

The large polypropylene capacitor called up for C2 is from Simens B32650 range and was purchased from **Electrovalue** (☎ *0784 433603 or 061-432 4945*), stock no. 502-2400 (2µ2).

Any readers who have difficulty finding a suitable xenon tube and "matching" trigger transformer, will find the "strobe" flash tube and the 4kV trigger transformer from **Maplin** are made for this circuit. These were used in the prototype and are coded FS78K (Xenon Strobe Tube) and YQ63T (4kV Trigger Trans.).

The one watt carbon resistors should be available from most component suppliers. However, the 100 ohm and 4·7 kilohm 3W and 10W wirewound power resistors may be listed by some advertisers as 4W and 11W types. Provided the resistance values are correct higher wattage types can be used. The resistors should be the ones sealed in a "cement box" or ceramic.

The high voltage power MOSFET type IRF830 took some tracking down, but is currently listed by **Cricklewood** (☎ *081 452 0161*) and **Electromail** (☎ *0536 405555*). The metal tab on the device used in the model was not isolated and was "live" so should not be touched when the power is on.

The mains transient suppressor was obtained from Maplin (code HW13P), but should be available from most advertisers. Transistor opt-isolator i.c.s are available generally and should not cause any buying problems. This device is included to ensure safety when using an external trigger set-up and must not be omitted from the circuit.

The metal case housing the strobe components must be "earthed" by bolting the mains Earth (E) lead, via a solder tag, to an area of bare metal. The printed circuit board is also connected directly to the mains supply and the unit should not be run with the case open, exposing the board. The printed circuit board is available from the *EPE PCB Service*, code EPE 843.

Personal Stereo Supply

We do not expect too many problems to arise when constructors stock up for the *Solar Personal Stereo Supply* project. Most of our component advertisers stock excellent ranges of cases and should be able to offer one with a sloping front panel.

The variation in the price we have quoted in our components "price box" is dependent on solar cells and more particularly the batteries used and if a panel meter is included. The 60mm x 46mm panel meter is the most popular size and prices range from £6 to £10 each.

The specified Schotly barrier diode is not stocked by all component suppliers, in fact, it only appears to be stocked by **Electromail**, code 657-117 (type SB130). You can, of course, opt to use the 1N4001 rectifier diode provided you are prepared to accept the resulting sharp decrease in performance.

Finally, this leaves the solar cells. If you decide to use the individual cells type G200, these are available from **Marco Trading** (☎ *0930 232763*) or **Greenweld Electronic Components** (☎ *0703 236363*) for about £1.60 each. The amorphous panels, also used in the prototype, were purchased from **Bull Electrical** (☎ *0273 203500*), code 4P155 and cost £4 each. Another company who specialise in solar cell is **Keysolar Systems**, see *Classified* ads.

Mind Machine MK II – Computer Interface

Nearly all the components needed to complete the *Mind Machine MkII – Computer Interface* are standard items. However, the "micropower" voltage regulator type LP2950CZ seems to be only listed by **Electromail**, code 648-567.

When ordering remember to specify "low current" types for the two l.e.d.s. The printed circuit board for the interface is available from the *EPE PCB Service*, code 833 (see page 547).

We do not expect any component buying problems to be encountered when ordering parts for the *Electronic Gong*. An excellent range of mains transformers are stocked by **Jaytee Electronics Services** (☎ *0227 375254*) and they will be able to recommend a suitable type. The printed circuit board is available from the *EPE PCB Service*, code 835.

FOX REPORT

by Barry Fox

NO AMSTRAD APPRAISAL

I have been following the notes and correspondence on Amstrad's fax machines with great interest, because I too have had some troubles and can add quite a lot of background. I suspect it all adds up to a good explanation of why Amstrad is now in its much publicised financial difficulty.

People who buy domestic audio and video equipment may get angry if it goes wrong, but their voice is seldom heard. For many years Amstrad has made a point of not providing this equipment for magazine review. So it is seldom appraised. The press are told when new models are launched, but not when old models disappear.

Amstrad is also cagey about supplying computer gear to the press, I have many times filled in the "request for loan" forms which Amstrad gives the press when new PCs are launched, but the only one I ever got to try was the low cost portable which Amstrad obviously felt safer in supplying. When I specifically asked for the loan of a satellite receiver (with MAC decoder) I asked for help getting it to work, but never got any before the loan was very quickly called in.

In December 1989 Amstrad launched the FX9600T fax machine. It broke new ground with large memory store for numbers, Mercury button, and socket for direct connection to the parallel printer port of a PC. So the unit worked as a photocopier or computer printer and sent text direct from a PC.

It also worked as a scanner, reading and memorising a signature for adding to the end of PC-sourced text. Amstrad also provided an output socket so that the machine could scan documents for a PC. Amstrad left it to third parties to sell control software for this. But none did because the machine soon disappeared without ceremony.

I got to try the FX9600T because I planned to buy one as well as write about it. I wanted to check it with Mercury, and with a computer. It worked well, but only after I had given up on the instruction manual and found by trial and error that the secret Mercury authorisation code must be entered twice instead of once as indicated in the instruction manual. I also had to find by trial and error that an unmentioned switch on the fax machine must be set to "on line" before it will accept text from a computer. This is not what business users want from a manual.

Worse still, just as I was on the point of paying to keep the machine, the LCD screen suddenly displayed garbage. The machine then locked up and refused to operate. The only cure was to unplug from the mains and remove the memory back-up batteries, to "cold start" the machine. This did the trick, but lost all stored numbers and codes that I had spent half a day entering.

Amstrad later said they traced the fault to static electricity generated by some brands of paper on the plastic sheet feeder. The fix, said Amstrad, was an anti-static strip to be provided on the feeder tray in all future machines. I never saw any modification. I did not believe the excuse then, and I do not believe it now. I just counted myself lucky that I had not yet paid for it.

LAST TRY

Last year, I decided to give Amstrad one more try, buying the ubiquitous FX-6000AT when my local Rymans was offering it on a good deal. The answer machine speech level is too low and the paper cutter soon failed, so it went back for repair. After repair, the paper cutter still did not work. Then the machine started giving error messages when it received more than a few lines of black. The LCD said it was "overheating" and the instruction book told me to "remove the machine from direct sunlight", even though it was mid-winter.

After quite a few phone calls, during which I had to describe the fault to a succession of different people, an engineer arrived believing that he had come to repair a different fault seen on another machine, over-heating of the mains transformer. On test the machine refused to over-heat on black and the engineer explained that there was no adjustment he could make anyway.

At this stage I called it a day and just have to hope that people do not send me faxes with too much black in them. I shall keep the FX-6000AT until it expires, then junk it and buy a fax from someone other than Amstrad. The bottom line is that I would rather spend a bit more and have less hassle.

I suspect a lot of other businesses now feel exactly the same way. And Amstrad will find that although it was easy to win a healthy share of the business market, with low cost PCs, it will be much harder, verging on impossible, to win back the share lost through tales of poor reliability. When business equipment lets someone down, whole company orders are lost and the word spreads like wildfire.

For the record, I would not now buy another fax that uses thermal paper. It is expensive and fades, apart from being horrid to write on. We shall soon be seeing a revolution in plain paper faxes which use bubble jet technology. Canon has already launched a first model, and lower cost units will follow. More on BJs later.

PAY-PER-VIEW TAPING

Although I have no sympathy for Amstrad's problems, because they are surely self-inflicted, I still have to hand it to the company for coming up with clever ideas, ahead of the game. A recent British patent application (2 257 557) from Amstrad tells an interesting story.

More and more satellite broadcasts are now scrambled or encrypted, usually using the Videocrypt system, and viewers must pay a subscription to watch them. A smartcard controls a decoder which unscrambles the signal. But as more and more channels scramble, and ask for a subscription, viewers find they are paying heavily for services they have not got time to watch.

This is creating the right market climate for "pay-per-view" TV. Videocrypt decoders are already designed to "suck" payment credits from a smartcard when the viewer presses an "accept" button to watch a selected programme. But Amstrad has smartly spotted that video recorders will not be able to tape PPV programmes when viewers are out. The video recorder can turn itself on under the control of a timer, but there will be no-one to press the accept button.

So Amstrad is patenting a video recorder for a combined satellite receiver, decoder and video recorder with an extra function in the timer. This lets the viewer pre-programme the VCR to generate a control signal which mimics the accept command. So the VCR will switch itself on, start taping a PPV programme and authorise the payment needed to unscramble it. Neat.

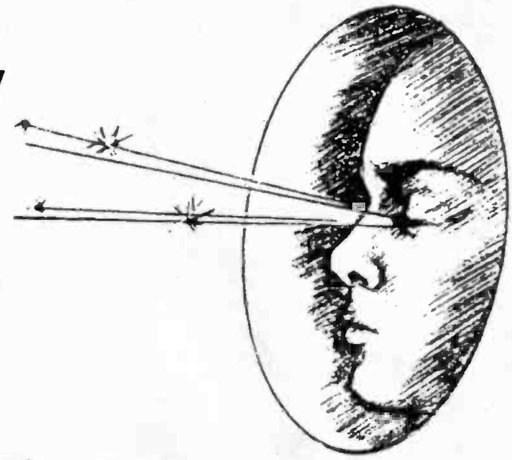
MERCURY CODE WARNING

Talking above about junking a fax machine prompts an important warning. Before junking any telephone or fax machine, or even returning one for repair, be sure to wipe clear the Mercury memory.

If you have a Mercury authorisation number, to use the Mercury network for long distance calls, then that number will be good for any location in the same phone code area, e.g. 071, 081, 061 etc. The advantage of this is that it lets Mercury subscribers use one authorisation number on several lines, with different exchange numbers, and at several locations. So the same authorisation covers phone line, fax line, home phone and office phone, with all calls charged to a single bill.

The disadvantage is that if anyone else gets hold of the authorisation number they will often be able to use it to make calls on your bill, from their phone. They can even sell the number to any number of other people. They will all then be able to make calls at someone else's expense.

MIND MACHINE MkII COMPUTER INTERFACE



ANDY FLIND

Part Three

Let your computer help you to relax! Build up a library of relaxation "tapes" for the popular Mind Machine MkII with this add-on interface

THE *Mind Machine MkII* – Binaural Signal Generator project of the April issue has just one disadvantage, that of boredom whilst making the tapes! The very pure nature of the sound tends to emphasise the usual "hiss", "crackle" and "pop" associated with re-recording, even with Dolby.

As the preferred format is a C60 tape with the same program on each side, to eliminate rewinding after use, the recording process is tedious. An automatic recording method was therefore sought, preferably using an existing programmable device as a controller. From pocket organisers to PC computers, the world is full of "bleeping" things which could be utilised.

At the outset, the top contender was a Psion "Series 3" pocket computer. Unfortunately this particular toy is no longer with the author, nor, alas, is it's predecessor, an LZ64 Organiser. However, a Sinclair Z88 is still around so this, with the BBC "BASIC" programming language, became the basis for the project.

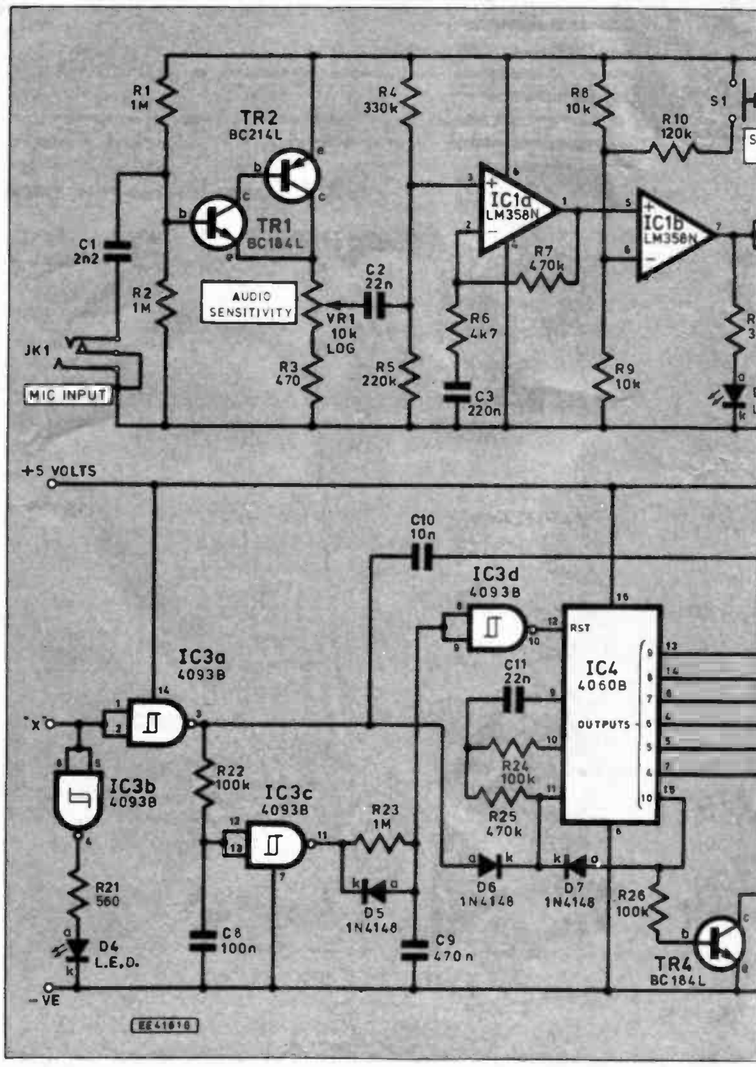
SILENT DESIGN

The first design generated a control voltage proportional to the length of "bleep" from the computer. This was later modified to the length of silence between two bleeps, because Sinclair's BASIC offers only fixed-length bleeps. It also improved immunity to external noise and enabled operation from an RS232 port, bypassing the audio altogether where this output is available.

Construction and use of the interface is fairly straightforward, although a computer and some experience of programming is necessary. The Binaural sequences are entered as "Data", and a program can be written to offer a variety of them and run the user's choice by selecting from a "library".

CIRCUIT DESCRIPTION

In the full circuit diagram, Fig. 1, the audio section begins with the microphone



input signal at JK1 being presented to capacitor C1. A crystal microphone is used for low cost and high output. The buffer stage of transistors TR1 and TR2 provides the necessary high matching impedance.

The signal then passes through sensitivity control VR1 to amplifier IC1a, which provides a voltage gain of about a hundred. Capacitors C1, C2 and C3 shape the frequency response from a few hundred Hertz (Hz) to about five kilohertz (kHz). Resistors R4 and R5 set the d.c. output from IC1a to two volts, upon which the amplified audio signal is superimposed.

The reference voltage of the comparator IC1b is half a volt higher than the input d.c. level so the output is normally low, only going high when the superimposed audio exceeds one volt peak-to-peak. This is indicated by the light emitting diode (l.e.d.) D1.

The best immunity to external noise is achieved when the sensitivity is just sufficient to respond to the desired bleeps, so pressing switch S1 lowers sensitivity by twenty per cent. The gain is adjusted to the threshold of operation and S1 is released, leaving the circuit with the correct sensitivity margin.

The comparator output is buffered and inverted by IC2a. Capacitor C4 is discharged immediately by diode D2 but recharged through resistor R12, so a series of pulses from IC2a produces a steady low voltage. Resistor R13 and capacitor C5 introduce a delay of about 100mS.

Much external interference is of the brief "pops and bangs" variety and is rejected by this delay. If the signal is of this nature, diode D3 ensures a rapid reset. IC2b buffers and inverts the output from C5, turning on transistor TR3 through resistor R19.

DATA INPUT

The "Data" input at JK2 is through capacitor C6. An a.c. signal applied here, such as a serial ASCII character, will also turn on transistor TR3. To simplify connection the signal polarity is unimportant, this being achieved as follows.

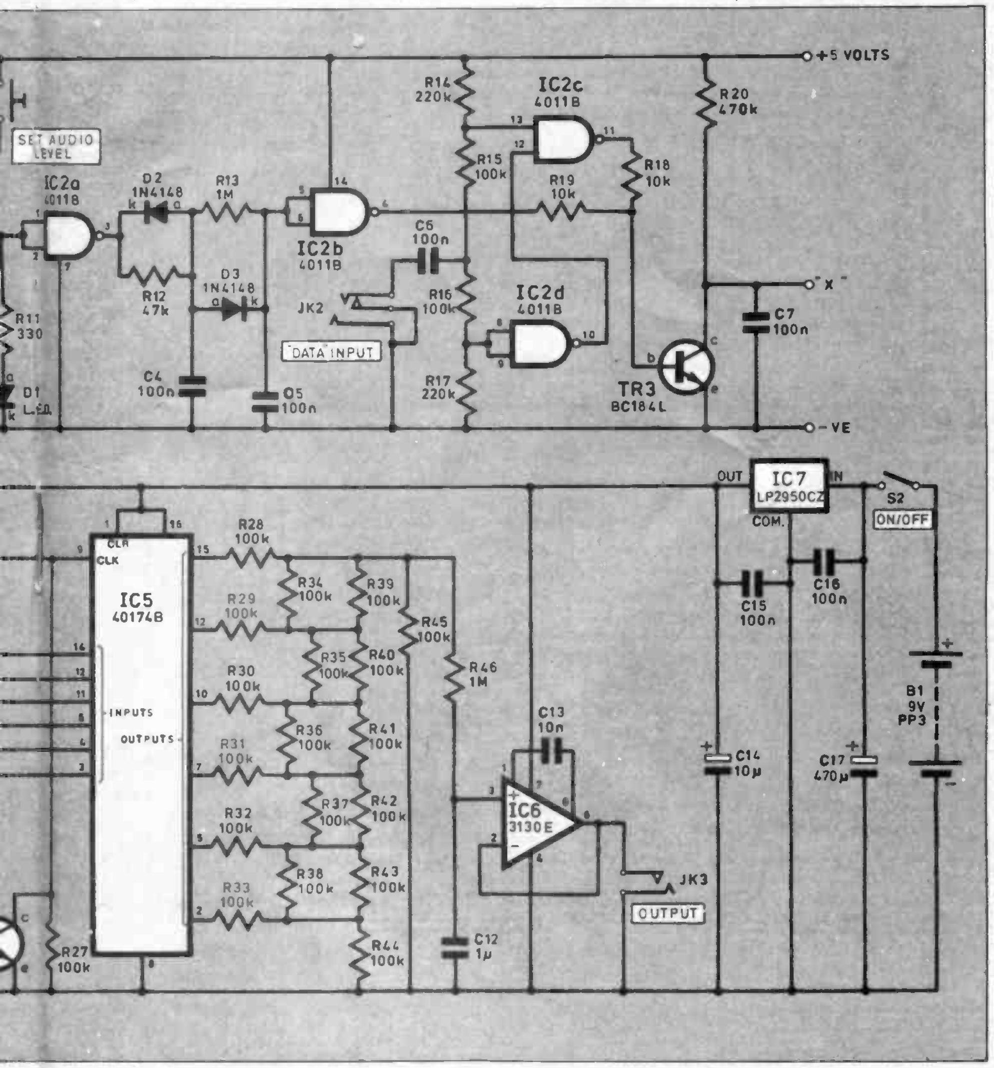
The junction of resistors R15 and R16 is normally at half the supply voltage so the input to IC2d is low (less than half supply), the resulting high output going to one input of IC2c. The other input to IC2c is also high, being greater than half the supply.

If the signal applied through capacitor C6 goes high, the output of IC2d goes low, causing the output of IC2c to go high. If it goes low, the other input of IC2c goes low so it's output still goes high. Either way IC2c output turns on transistor TR3 through resistor R18.

When TR3 is energised by an audio or data signal, it discharges capacitor C7, normally kept charged by resistor R20. The output at point "X" is therefore a "low" pulse which lasts at least the fifty milliseconds recharging time.

When this point goes low, the output of IC3b goes high, illuminating l.e.d. D4 to indicate a received signal. IC4 is a 14-stage counter with an integral oscillator. Six stages, numbers 4 to 9, are taken as outputs. If an input has not been received for some time, the next stage output, num-

Fig. 1. Complete circuit diagram for the Mind Machine Computer Interface.



COMPONENTS

Resistors

R1, R2, R13, R23, R46	1M (5 off)	
R3	470	
R4	330k	
R5, R14, R17	220k (3 off)	
R6	4k7	
R7, R20, R25	470k (3 off)	
R8, R9, R18, R19	10k (4 off)	
R10	120k	
R11	330	
R12	47k	
R15, R16, R22, R24, R26 to R45	100k (24 off)	
R21	560	

All 0·6W 1% metal film.

See SHOP TALK Page

Potentiometer

VR1	10k rotary carbon, log.

Capacitors

C1	2n2 polyester layer
C2, C11	22n polyester layer (2 off)
C3	220n polyester layer
C4, C5, C6, C7, C8, C15, C16	100n polyester layer (7 off)
C9	470n polyester layer
C10, C13	10n polyester layer
C12	1µ polyester
C14	10µ radial elect., 50V
C17	470µ radial elect., 16V

Semiconductors

D1, D4	Red low current l.e.d. (2 off)
D2, D3, D5 to D7	1N4148 silicon signal diode (5 off)
TR1, TR3, TR4	BC184L *npn* transistor
TR2	BC214L *pnp* transistor
IC1	LM358N dual op-amp.
IC2	4011BE CMOS quad NAND gate
IC3	4093BE CMOS quad Schmitt NAND gate
IC4	4060BE CMOS 14-stage divider with internal oscillator
IC5	40174BE CMOS Hex latch
IC6	CA3130E op.amp.
IC7	LP2950CZ 5V positive regulator, micropower type

Miscellaneous

S1	Press-to-make, momentary action, switch
S2	SPST on-off switch
JK1, JK2	3·5mm switched mono jack socket and plug (2 off)
JK3	Output socket 3·5mm mono jack socket and plug
B1	9V PP3 battery, with connectors

Printed circuit board available from *EPE PCB Service*, code 833; 8-pin d.i.l. socket (2 off); 14-pin d.i.l. socket (2 off); 16-pin d.i.l. socket (2 off); plastic case to choice, see text; control knob; connecting wire; solder etc.

Approx cost guidance only **£23** *excl. case* ber 10, will have gone high and stopped the oscillator through diode D7. Transistor TR4 is also turned on by this output to prevent operation of the "CLK" input (pin 9) of the hex latch IC5.

When point "X" goes low and IC3a output goes high, therefore, there will be no change in the latch outputs. After the delay of 100mS, set by resistor R22 and capacitor C8, the output of IC3c goes low, taking IC3d input low immediately via diode D5 so IC3d output goes high, resetting the counter.

When the input signal ceases resistor R23 and capacitor C9 delay removal of the reset signal from IC4 for about half a second, after which the oscillator runs and the counter outputs commence their binary output sequence. If another input is received before pin 15 of IC4 goes high, the following sequence takes place.

The oscillator is stopped immediately via diode D6. Simultaneously, a one millisecond pulse from capacitor C10 to the CLK input of IC5 transfers the six outputs of IC4 to the outputs of this chip. From here they are converted to a d.c. voltage by the "R-2R" network of resistors R28 to R44. Resistor R45 adjusts the final output level, sudden changes are smoothed by R46 and C12, and IC6 buffers the output.

If a second input is not be received in time, the oscillator continues until pin 15 goes high, and the circuit reverts to the original state. The relatively long delay of resistor R23 and capacitor C9 allows a second input to be sent before the oscillator starts, so an output of zero is possible.

The circuit is supplied by a PP3 battery regulated to 5V by IC7, a "micropower" regulator. This uses less power than a 78L05 and can operate with a smaller voltage differential, saving on batteries.

VARIATIONS

Before proceeeding to construction, some possible variations should be mentioned. For instance, the power drain is small, so it can operate from the 5V supply of associated equipment. If so, it is suggested that capacitors C14 and C15 are retained, but IC7, C16 and C17 can be dispensed with and the supply connected to IC7 output point.

Another saving can be made if the unit is always to be driven from a serial port. In this case IC1 can be omitted, together with S1, VR1, l.e.d. D1, all resistors up to R13 and capacitors to C5. However, the inputs to IC2a and IC2b will have to be linked to ground, as CMOS inputs should never be allowed to float. The way to do this is shown in Fig. 2.

The author has a "stripped down" board of this type installed in the original *Mind Machine* allowing operation from computer instead of the internal memory. For constructors who might wish to try this the connections are shown in Fig. 7. The "stripped-down" board has space and tracks to spare for mounting holes etc, and can be installed above the two existing *Mind Machine* p.c.b.s. The two extra components can be fitted on unused sections of track from the audio section.

CONSTRUCTION

Most of the Computer Interface components are mounted on a single-sided printed circuit board. This board is available from the *EPE PCB Service*, code 833.

Construction is straightforward, there are no particular points to watch. Most of the i.c.s are CMOS, so the usual precautions against static damage should be observed

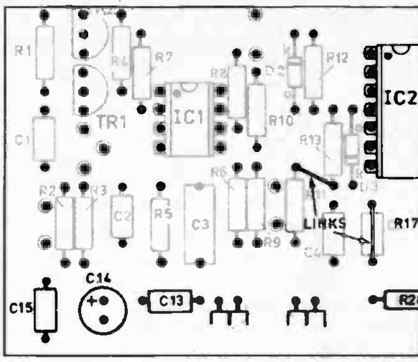


Fig. 2. Component savings can be made if the unit is always driven from a serial port. Tinted components are removed and input "ground" links inserted.

The positions of all components, together with a full size underside copper foil master pattern, are shown in Fig. 3. Some of the vertically mounted "R-2R" resistors are not labelled due to lack of space, but all resistors installed vertically are 100 kilohm types. D.I.L. sockets are recommended for all i.c.s except IC7. The i.c.s should not be inserted yet as a step-by-step test procedure follows.

Layout in the case is also not critical, the arrangement of the prototype can be seen from the photographs although individual constructors may prefer to instal it in a case with the generator, using the same power supply, or may not even bother to house the board at all if it is only to be used for making tapes at home. Interwiring connections to the controls, input and output sockets are shown in Fig. 4.

TESTING

The following test sequence assumes that the complete unit has been built, including power supply and audio stage. Sensitivity control VR1 can be connected and the board powered, with the current drawn being monitored. As usual there should be a surge as capacitors, primarily C17, charge, after which the drain should settle to around 0·5mA to 0·6mA.

The five volt regulated supply can be checked, the top of capacitor C15 being a good access point for this, followed by the potential at the top of VR1, which should be approximately 2V. If this is OK, the unit should be switched off for the connection of l.e.d. D1 and the microphone (with screened lead) and insertion of IC1. This raises the drain to about 1mA.

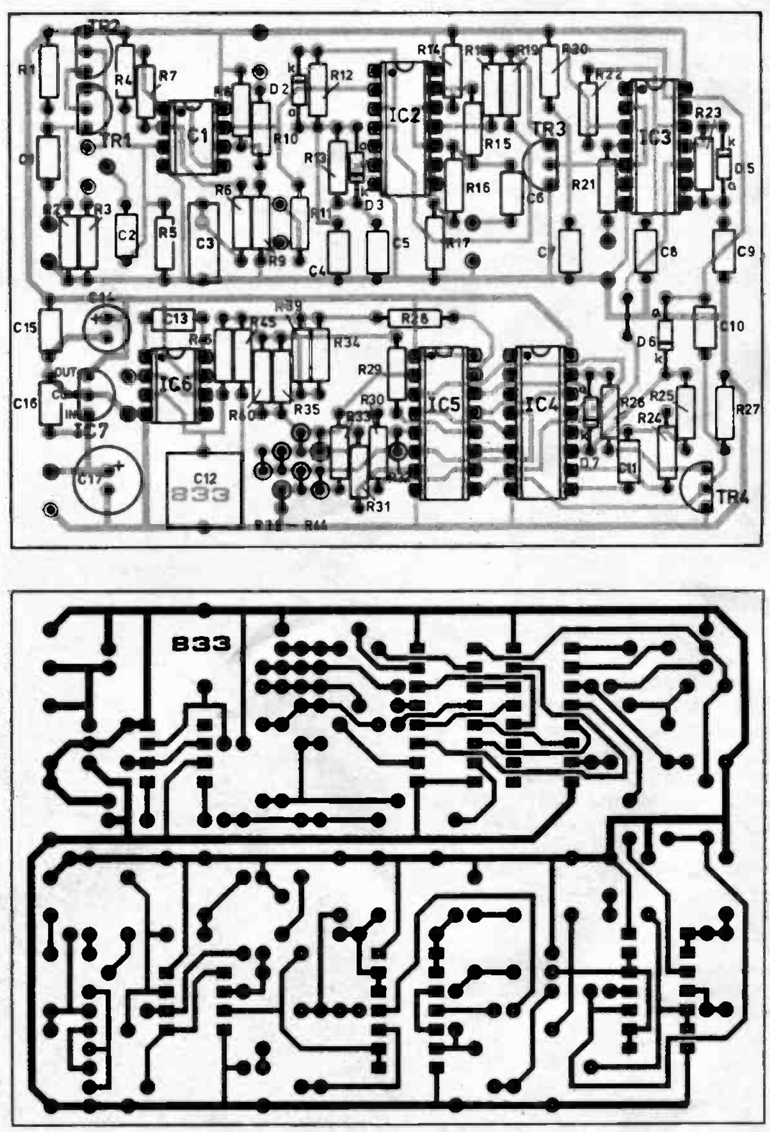


Fig. 3. Printed circuit board component layout and full size underside copper foil master pattern.

There should be about 2V at IC1 pin 1 and if VR1 is turned up, a loud noise, such as a whistle, should light l.e.d. D1. After this, IC2 can be inserted. The drain will still be around 1mA.

Point "*X*" (from the bottom of resistor R20, or pin 1 of IC3 socket) should be monitored with a voltmeter. The actual reading will depend on the meter impedance as it is derived from the 470 kilohm resistor R20, but it should fall to zero whenever a noise causes D1 to light.

Next, l.e.d. D4 can be connected and IC3 inserted. Noise should light both l.e.d.s, but the brief delay before l.e.d. D4 lights may be observable. A wire connected to the "data" input (C6) and alternately touched to 0V and 5V (top and bottom of capacitor C15), should cause l.e.d. D4 to flash.

If IC4 is inserted and pin 15 monitored, this should be high, going low when a sound is received. When the sound stops it should stay low for three to four seconds before returning high.

The Hex latch IC5 can now be inserted and the top of resistor R45 or R46 monitored with the voltmeter. A whistle lighting the l.e.d.'s, followed by another within a couple of seconds, should produce a steady voltage. Another whistle, repeated after more than five seconds, should have no effect. If so, IC6 should be inserted and these tests repeated whilst monitoring the output.

As a guide, a half-second gap between signals gives about half a volt, two seconds about two volts, three seconds about three volts. Inputs longer than this are not accepted as the counter "times out".

LINK-UP

Connection to equipment to be controlled depends on the use to which it is to be put. The *Binaural Signal Generator* (April '93) can be fitted with a switched jack socket, selecting the Interface output in place of the control potentiometer wiper, or both units could be housed in the same case with a switch for input selection and a common 5V supply.

Linking to the controlling computer can also be through a jack socket, to either microphone or serial port. The microphone for the prototype was supplied fitted with a screened lead and 3·5mm mono jack plug at modest cost. The "data" input connections do not need screening. Both (JK1, JK2 sockets are arranged to switch their inputs to ground (−V line) when the jack plugs are not inserted.

Where the microphone is used, it should be placed as close as possible to the sound source. For the prototype this was a Sinclair Z88, which has a piezo "speaker" beneath the front right-hand side. Sheet foam plastic was cut and shaped to aid positioning of microphone and computer, the optimum site being located with the "continuous bleeping" program "PROG1" and judicious adjustment of control VR1. Similar methods can be used with other machines, such as Psions.

Connections for a "data" input lead will depend on the computer used and it's serial port, reference to the manual should be made. The aim is to connect the data output to the interface input whilst linking "handshaking" lines high or low at the computer to allow it to send.

The program can then "write" characters to the serial port to operate the interface. Connections for a Sinclair Z88 lead are shown in Fig.5. Settings used for transmission were Baud Rate: 9600 (both), Parity: none, and Xon/Xoff: yes.

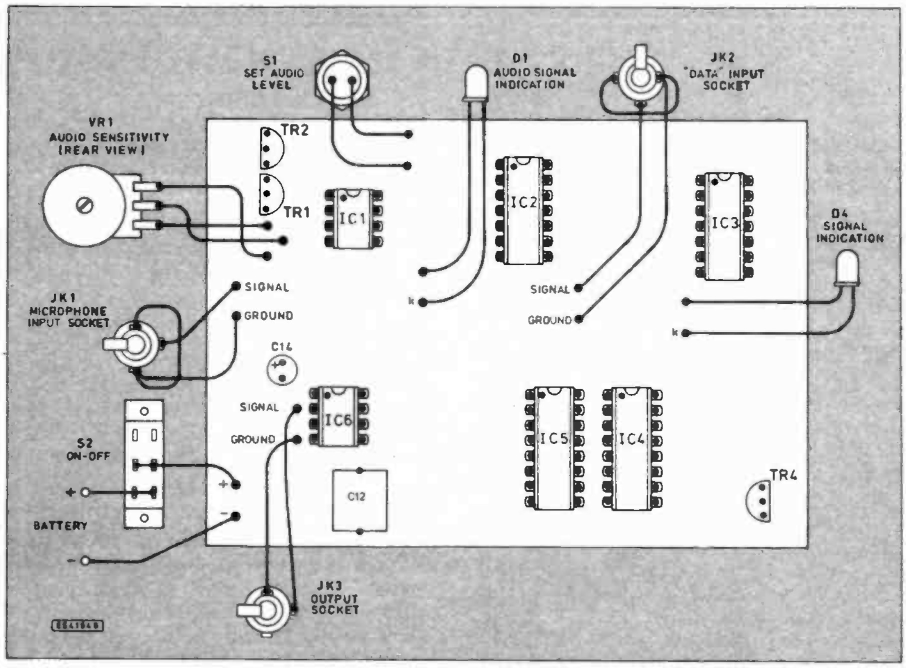


Fig. 4. Interwiring to the controls and input and output sockets.

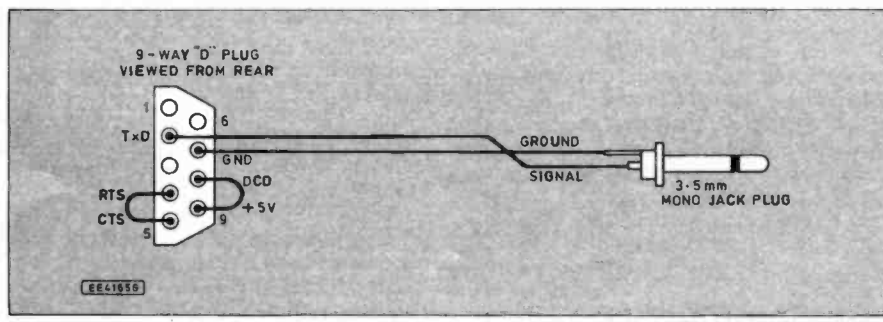
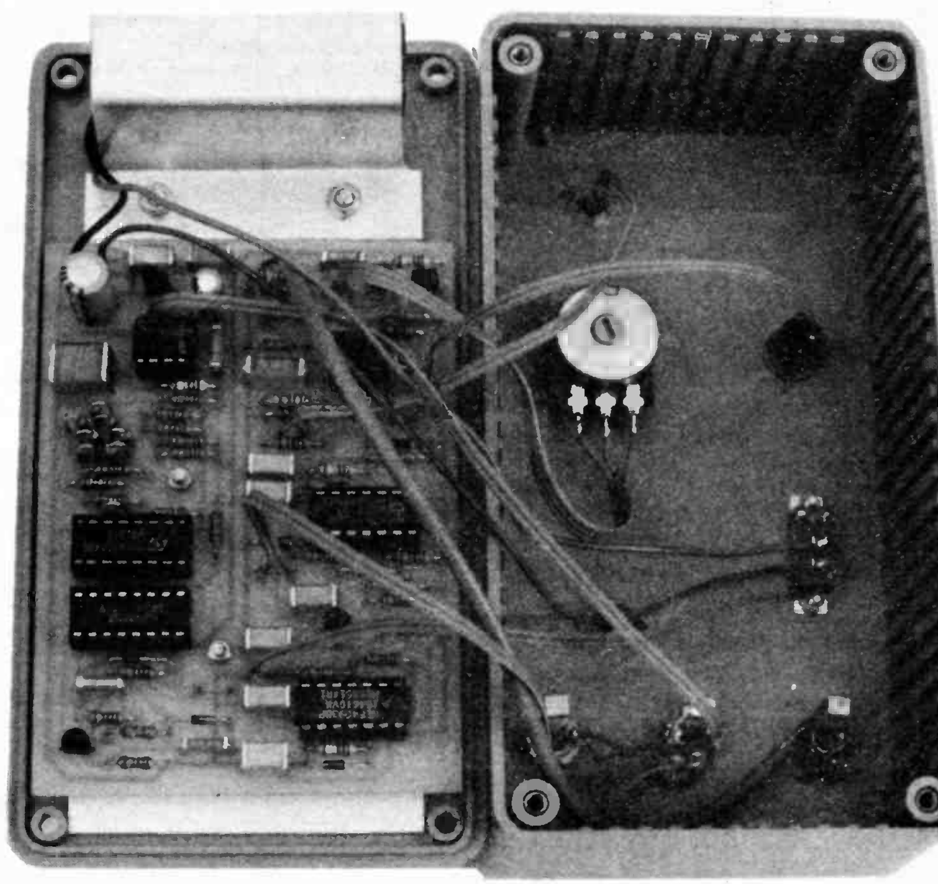


Fig. 5. Connecting lead wiring for a Sinclair Z88 Serial Port. For connections to other machines refer to manufacturer's manuals.



SOFTWARE

With the hardware complete, the project requires a program. Writing expertise required is quite low, so long as the programmer understands how to generate timing intervals, bleeps, and perhaps send characters to the serial port.

It is also helpful to display messages on screen, and some "array" handling and arithmetic are used. The programs given are in "BBC BASIC" on the Sinclair Z88, though other languages such as "C" or Psion's "OPL" might be used.

"PROG1" is a test program to provide bleeps and data pulses every 0·75 second, for testing and audio sensitivity adjustment. The statement "VDU7" causes the Z88 to emit a 3kHz bleep for 200mS. This sound is recommended where other computers are used with this project.

The first line "opens" the serial port with file handle "P", so that the character, "0", sent to "P" by the command "BPUT#P,0" is transmitted. If the data output is not required line 10 and the ":BPUT..." part of line 20 can be omitted.

In line 30, "Time=0" resets the internal "clock" to zero. "REPEAT" then loops until the clock is greater than 75; as the Z88 clock counts in 100ths of a second this produces a 0·75sec. delay.

"PROG2" allows the effect of time between signals to be tested. It requests entry of a time, in 100ths of a second.

Line 40 then introduces a one-second delay so that the microphone input is not disturbed by the tapping of fingers on the keyboard, after which two sound and data signals are sent separated by the time value entered. This may be used to find the "zero" and "steps per volt" values for the interface.

The full program, Listing. 1, aims to control the *Mind Machine MkII – Computer Interface* so that the *Binaural Signal Generator* produces the desired frequency sequences over set time periods. The sequences are entered as "data" in the program, and it is obviously better if this can be entered as actual frequencies.

Test Programs

"PROG1"

```
10 P=OPENOUT(":COM.0")
20 VDU7:BPUT#P,0
30 TIME=0:REPEAT UNTIL
   TIME>75
40 GO TO 20
```

Function:
Emits bleeps and data pulses every 750 milliseconds. For testing and setting audio gain level.

"PROG2"

```
10 P=OPENOUT(":COM.0")
20 CLS
30 INPUT"Time? "T
40 TIME=0:REPEAT UNTIL
   TIME>99
50 VDU7:BPUT#P,0
60 TIME=0:REPEAT UNTIL
   TIME>T-1
70 VDU7:BPUT#P,0
80 GOTO 30
```

Function:
Requests a time value T, then pauses one second (to avoid key noises interfering with mic input), then delivers a pair of bleeps and data pulses with time spacing T.

The computer can calculate the control voltage and corresponding period between signals for each value. A slight snag is that since the Binaural Generator output frequency is related to the time-constant of capacitor C12 and resistor R11 in it's circuit, the relation between control voltage and output frequency contains an "exponential" function.

The first step in writing the program is to find the "zero" and "per volt" timing values for the particular interface and computer in use. If the "audio" input is to be used, "PROG1" or similar should be used to position the microphone and adjust sensitivity, whilst a "data" input lead can be simply plugged in.

Using "PROG2" or similar, various time values can be tried to find those corresponding to zero and three volts, "zero" being the highest value producing no output. Using the "data" input with the prototype and the Z88, which measures time in 100ths of a second, these values were 44 for zero, and 280 for three volts.

From these the value-per-volt can be calculated, in this case (280-44)/3 = 78·67 per volt. For a given output "V" in this case, the value for "time" is therefore (Vx78·67)+44. This was checked out for various voltages to prove it's validity.

CONTROL PROGRAM

The full program, "CTRL", operates as follows: Line 10 defines an array to hold 121 values. Line 20 generates an announcement on screen, and line 30 calls the procedure "PROCstart".

This obtains the user's preference from the programs available, setting the data "pointer" to the appropriate data line number. It also requests selection of the running time, but rejects values below fifteen minutes.

"PROCload" loads the array with 121 frequency values. Each set of data contains thirty one values, but to make control action smoother three intermediate values between each pair are calculated and entered in the array.

"PROCrun" then converts each array value into the appropriate output value and sends it at the correct time. It works as follows:

The "clock" is set to zero by line 410. Line 420 opens the serial port as the output device. Next a loop begins, for 121 operations using the loop counter "N". Line 440 adds the timing interval "I" to a running total "T". Frequency "F" is read from the array. Lines 460 to 480 print the elapsed time and current frequency on screen, using the function "FNround" for rounding these to one and two decimal places respectively. Line 490 converts the frequency to the appropriate output voltage.

Line 490 is a compromise, with the values given it uses a "square" function to produce an output within a couple of percent of the true exponential one. Perfectionists can replace it by the four lines of Fig. 6, but it is unlikely that this will offer a worthwhile improvement.

Line 500 converts the voltage into the delay period between outputs, here the values obtained for "zero" and "value-per-volt" should be inserted in place of those shown. Line 510 sends the ASCII for "0" to the serial port, if a "bleep" is required, the code for it should be added here. Line

Fig. 7. Details of connection of the Interface board to original Mind Machine.

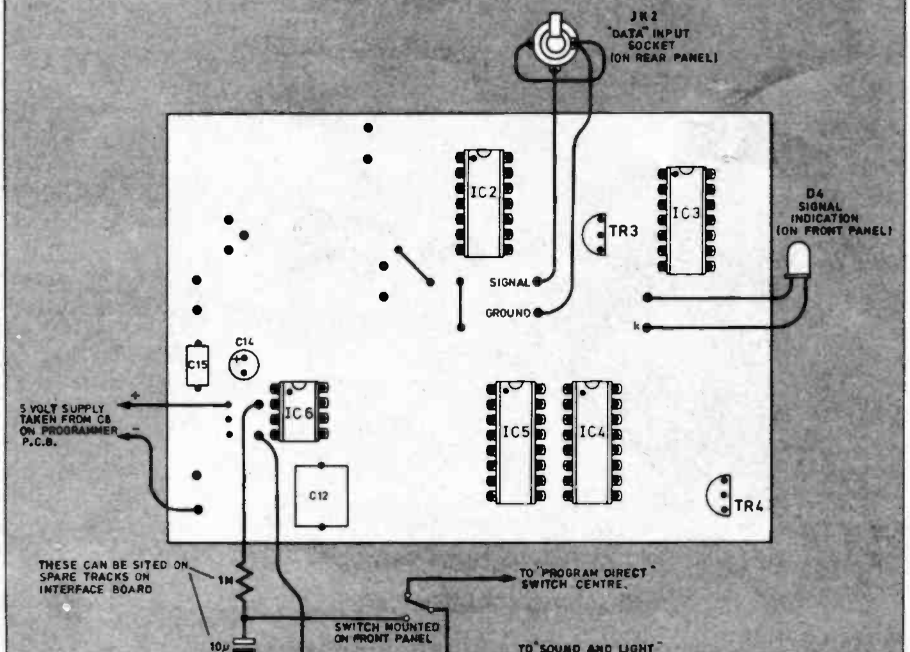


Fig. 6. Extra Lines for True Exponential Output.

```
490 F1=1.5E6/4096:P1=1/F1
491 F2=F1-F:P2=1/F2
492 F=(P2-P1)/2
493 F=5*(1-EXP-(F/100E-6))
```

Listing 1: Main Control Program

"CTRL" – Main control program for interface.

```
10 DIM A(120)
20 CLS:PRINTTAB(8,0)"MIND
    MACHINE CONTROLLER..."
30 PROCstart
40 PROCload
50 PROCrun
60 CLS
70 PRINTTAB(5,5)"End of run
    ... Ready to repeat."
80 FOR X=0 TO 5
90  VDU7
100  TIME=0:REPEAT UNTIL
      TIME>100
110 NEXT
120 END
130 :
140 DEFPROCstart:REM Obtain
     selection of program
     and time.
150 VDU7
160 INPUTTAB(10,2)"Select
     your program...     "X$
170 X=FALSE
180 IF X$="A" RESTORE 630:X=TRUE
190 IF X$="B" RESTORE 650:X=TRUE
200 IF X$="C" RESTORE 670:X=TRUE
210 IF NOT X THEN 150
220 VDU7
230 INPUTTAB(10,4)"Select run
     ning time in minutes... "I
240 IF I<15 VDU7:PRINTTAB(10,6)
     "15 or more please!
     ":TIME=0:REPEAT UNTIL
     TIME>100:GOTO 230
250 I=I*50
260 ENDPROC
270 :
280 DEFPROCload:REM load array
     with 121 values of freq.
290 LOCAL N,P,X
300 READ A(0)
310 FOR N=4 TO 120 STEP 4
320  READ A(N)
330  X=(A(N)-(A(N-4)))/4
340  FOR P=1 TO 3
350   A(N+P-4)=A(N-4)+X*P
360  NEXT P
370 NEXT N
380 ENDPROC
390 :
400 DEFPROCrun:REM Run series
     of output values.
410 TIME=0
420 P=OPENOUT(":COM.0")
430 FOR N=0 TO 120
440  T=T+I
450  F=A(N)
460 M=TIME/6000
470 PRINTTAB(10,6)"Time elapsed:
     ";FNround(M,1);" minutes. ";
480 PRINT"  Current frequency:
     ";FNround(F,2);" hertz.    "
490 F=F/5.471-F^2/430
500 F=F*78.67+44
510 BPUT#P,0
520 F=F+TIME:REPEAT UNTIL TIME>F
530 BPUT#P,0
540 REPEAT UNTIL TIME>T
550 NEXT N
560 ENDPROC
570 :
580 DEFFNround(K.L):REM rounding
     off for time and freq.display
590 K=(K*10^L)*10:K=INT(K)/10
600 IF K-INT(K)=>0.5 K=K+1
610 =INT(K)/10^L
620 :
630 DATA 18,14,11,11,12,12,11,
     9,7,6,7,9,11,11,10,8,8,10,
     11,11,10,10,12
640 DATA 13,11,10,10,11,12,14,18
650 DATA 19,14,12,10,12,9,11,
     7,9,8,8,7,7,4,6,7,3,5,4,
     3,7,4,8,6,10
660 DATA 11,10,11,12,14,18
670 DATA 17,14,11,11,12,12,11,8,
     6,6,9,10,9,7,5,4,3,3,2,3,
     3,4,7,9,10,10
680 DATA 11,11,12,14,18
```

520 generates the appropriate delay, then line 530 sends the second output. Line 540 generates the appropriate interval between pairs of outputs, then the cycle repeats.

On completion of the last cycle, control passes back to line 70, where an "end of run" message is printed on screen and the computer bleeps five times to alert the user to the end of the sequence.

Lines 630 to 680 contain frequency data for three programs used by the author, occupying two lines each.

CHANGE OF MIND

This simple program is obviously open to modification and improvement, and may be re-written for use with other computers. As it stands, it has been used both for making tapes for the *Magic Lights* (Part 2 – May '93) project and for controlling the original *Mind Machine* during "real-time" sessions. It allows precise and repeatable control over sequences and is a vast improvement over manual tape creation.

With suitable software, the Interface project may find other applications where a computer-controlled voltage is required, especially where direct connection to the computer is difficult, as with some "palmtop" types. □

REPORTING AMATEUR RADIO

Tony Smith G4FAI

RECORD BREAKING MISSION

From an amateur radio point of view, the space shuttle *Discovery* (STS-56) launched on April 8 was a great success. All five crew members held amateur radio licences and the secondary payload was SAREX – the Shuttle Amateur Radio Experiment. This allows school groups and amateur radio operators to talk to the crew while they are in orbit.

The crew talked to students at a record 18 schools around the world, including two in Britain, answering questions about life in orbit. On April 10, they accomplished the first two-way amateur radio contact between two manned spacecraft, when the Russian *MIR* space station passed within 135km of the shuttle.

Another first was the use of experimental fast scan amateur TV, climaxing with live video images of the mission control room at the Johnson Space Centre being received by the shuttle as it passed over Houston

In radio terms, the mission was rounded off by slow scan TV, packet, and a few general contacts. A final 'first' arose from the fact that SAREX is now the only payload that has flown on all shuttle missions! *(W5YI Report)*

EARLY MORSE STARTER

Congratulations to Michael Hindley of Hull who passed the amateur radio 12 w.p.m. Morse test on 24 March this year. Why am I reporting this? Well, it was Michael's 8th birthday!

According to his father, Mike Hindley G4VHM, writing in *Morsum Magnificat* (the Morse magazine), Michael when aged 7 liked to listen to his dad sending CW (Morse) on the air.

One day he said "are you talking to G4PEP?", a local amateur. He had recognised the sound of G4PEP in Morse. From there, says Mike, "we just picked a word from the newspaper and I asked him to learn it in Morse for the following day. My daughter joined in so it became a family project with a test at the end of the week rewarded with a Mars bar!

"When we were out in the street, the name of the game was 'Say in Morse' the registration number of the car in front of us, the street name, the shop sign, and so on. We found this a good way to prevent travel sickness and journeys passed more quickly."

The target was for Michael to take the Morse test before his 8th birthday but in the event the earliest one he could book was actually on his birthday. He passed with flying colours and, says dad, "the Novice examination is the next step!"

RA TO DISCUSS MORSE TEST

It appears that the Radio Society of Great Britain's recent invitation to all UK amateurs and SWLs, to comment on whether they are for or against the idea of a code-free licence for amateur operation below 30MHz, had a hidden purpose

The impression was given that this was an RSGB initiative to enable the Society to decide on the attitude it should adopt in any future discussions on the no-code controversy. A report in the April issue of *Morsum Magnificat*, however, reveals that the Radiocommunications Agency itself asked the RSGB to seek a consensus view on the matter from the amateur community through RadCom (i.e., the Society's journal) because in recent years it has been receiving conflicting views on the subject; at the same time this request was extended to other amateur publications

As well as seeking input through these publications, the Agency has confirmed it will also accept the views of interested parties direct and all opinions will be taken into account when the matter is discussed later this year. Letters should be addressed to the Radiocommunications Agency, Waterloo Bridge House, Waterloo Road, London SE1 8UA, marked for the attention of Mrs Karen Scott, Room 712

RECIPROCAL LICENCES AT RISK?

New Zealand's national amateur radio society, NZART, recently proposed to their licensing authority, the Ministry of Commerce, that examinations for the New Zealand General Grade licence should cover an optional selection of alternative skills or technical knowledge standards in place of the present obligatory Morse test

In reply, the Ministry pointed out that under the international regulations no other nation allows code-free amateur radio except for operation above 30MHz; and that apart from breaching the regulations, such a licence would affect existing reciprocal agreements with other countries.

It declined, therefore, to consider the proposal at the present time. It suggested, however, that a co-ordinated approach from the International Amateur Radio Union to the ITU might clear the way for such a goal to be achieved later. *(W5YI Report)*

The point about reciprocal arrangements is important. These arrangements enable radio amateurs from one country to operate in other countries under the authority of their 'home' licence, provided it was issued under regulations comparable with those of the country visited.

If code-free h.f. operation was permitted in the UK as a result of the RA's forthcoming discussions, it is possible to visualise a situation where British amateurs, including the 33,000 existing class A licensees, would lose this valuable facility and would not be able to operate h.f. in other countries where the Morse test was still obligatory. At the same time Britain would become very popular as a holiday centre for foreign amateurs with code-free v.h.f. only licences, who would be able to operate h.f. here to their heart's content!

UNLICENSED OPERATING

The RA reports that 95 people were convicted for Citizens' Band offences in 1992. The highest penalty imposed was £668 plus costs, and in most cases the courts also confiscated equipment. Most offences were for unlicensed use, or for the use of illegal equipment such as linear amplifiers or amplitude modulation (a.m.) or single sideband (s.s.b.) sets

An Agency spokesman commented, "Illegal CB equipment is one of the main causes of interference to television and radio reception. It can also affect the emergency services, which rely on clear radiocommunications, so it can be life-threatening as well as anti-social."

Because CB licences are available without a need for examination, only type-approved low power transmitters may be used, designed to ensure that when used by inexperienced operators they will not cause interference to other radio services; and even the antennas used have built-in attenuation to restrict their range

Radio amateurs, of course, do not have these restrictions because they are required to demonstrate a certain level of competence by examination before receiving a licence. They may use a wide range of equipment, in a variety of transmission modes, at much higher power levels, and they have a wide choice of frequencies on which to operate

PRISON SENTENCE

The maximum penalty which a magistrates court can impose for unlicensed use of radio equipment is a fine of £5000 and six months imprisonment. Crown courts can impose an unlimited fine and up to two years imprisonment, and all courts can order forfeiture of equipment

As far as I know, no unlicensed operators have yet gone to prison in this country, and only one has ever received such a sentence in the USA. In 1984, Richard A. Burton of California was sentenced to four years, later reduced to six months, for unlicensed operation on the amateur bands. Now, according to the *W5YI Report*, he has just been sentenced to another seven months for further offences. He is quoted by the *Los Angeles Times* as saying "I think I need to get myself another hobby."

Teach-In '93

with Alan Winstanley
and Keith Dye B.Eng(Tech)AMIEE

Part 9

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 or GCE Advanced Levels.

EVERYWHERE we turn it seems that microprocessors are being incorporated into consumer products – from cameras to cars, or televisions to toys. They are being used in these products because they can add extra functions or offer more accurate control compared with many products which make do with ordinary technology. How? What's in a microprocessor that allows it to be used in all these different ways?

THE MICROPROCESSOR

A microprocessor is a collection of TTL circuits combined onto a single piece of silicon. Most of the separate parts themselves will be familiar to followers of the Teach-In series. There are counters, latches, adders, and other blocks which we will investigate in the next three parts of Teach-In. The TTL digital systems we have studied so far can only perform the one function they were designed for. The microprocessor is much more versatile because it can use the digital blocks in a variety of ways under control of an operating **program**. ("Program" is always spelled the American way in this area of microelectronics.)

Data Definitions

Microcomputers come with varying sizes of data and address buses. The type of CPU we will cover in Teach-In has an 8 bit data bus and 16 bit address bus. Microprocessors can have data buses from 1 to 64 bits wide. Address lines also vary in number according to the memory locations the CPU will have to address with the more powerful devices using 32 lines. In order to describe more accurately data and address numbers some new terms have become common in computing. The following table shows some of these:

1 bit	=	1 *binary digit*
4 bits	=	1 nibble
8 bits	=	1 byte
16 bits	=	1 word
32 bits	=	1 long word or doubleword

This versatility is the key to the success of the microprocessor. Circuits can perform many different tasks without the need to rebuild the components every time. Thus, a microprocessor is a "general purpose" logic unit, the operation of which can be customised or **programmed** to fulfil a particular role.

We will be investigating the fascinating and challenging world of programming in future parts. Meanwhile, we've been hard at work in developing some interesting experiments that use a microprocessor to allow you to measure and control other digital and analogue systems. If you have programmed computers previously, the practical aspects of the course should provide a fresh insight into the operation of the microprocessor.

ENTER THE MICRO LAB

To demonstrate the functions of a microprocessor, a *computer system* will be needed. We have designed a small but powerful computer – the ***EPE Teach-In Micro Lab*** – with which you will be able to:

- *Learn the fundamentals of microprocessor technology*
- *Write and test your own programs*
- *Store programs in the built in memory for future use*
- *Use Micro Lab as a stand-alone computer control system for experiments*
- *Run built-in demonstrations / test routines*

This exciting project will appeal to the more advanced readers of the series, GCSE and "A" Level students, as well as serious constructors who are looking for a microprocessor applications module. *Micro Lab* has been specially designed to support Teach-In, but due to the flexibility and power of the design it will find many uses as a stand-alone computer for controlling experiments and for learning more advanced programming.

To make the *Micro Lab* perform useful tasks, we have written a special program called a Monitor Program. This contains a number of ready-developed experiments (10 in all) and provides the framework for you to try your hand at programming. But before we can use a computer, we need to see how computers work.

COMPUTER SYSTEMS

A block diagram of a computer system is shown in Fig. 9.1. It could be any small home computer or a large industrial computer. Computers are designed to move information from one place to another. Computer information is called **Data**. The computer is controlled by a **Program** which contains the information on where to get the data from, what to do to the data, and where to send the data to.

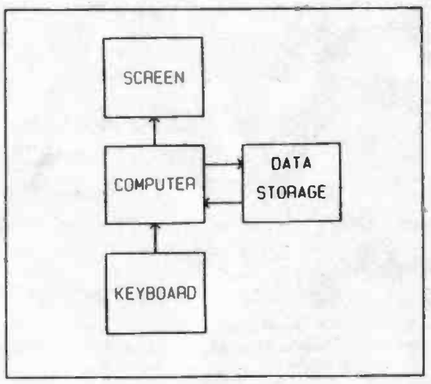


Fig. 9.1. Computer system.

In Fig. 9.1 the computer can get data from either the Keyboard or the Data Storage and send the data to the Data Storage area, or move the data to the Screen for display. The keyboard is an input device, and the screen is an output device. The data storage is both an input and output device.

Some of the subsystems that may be inside a desktop computer are shown in Fig. 9.2. At the centre is the microprocessor. We will often call this the **Central Processing Unit** or **CPU**. The microprocessor requires a data storage area called a **Memory**. This is where the operating program is stored. A keyboard cannot usually be connected directly to the microprocessor as the data output from the keyboard is incompatible with the data input requirements of the microprocessor. A Keyboard Interface circuit is needed to convert the data to overcome this.

Similarly, the microprocessor cannot send data directly to a screen. In this computer data is converted into the correct format by the Video Interface. The data store (which could be a disk drive) also needs its own interface.

The microprocessor is also able to alter the characteristics of the interface to match the system connected to it. In the case of the monitor interface it could be set to

The Social Impact of Electronics

MANY of our younger readers accept electronic devices as everyday objects. Electronic calculators, computers and computer games, television and video, fax machines, compact disc players, the microwave oven and many other consumer electronic systems will be familiar to them just as the slide rule and "log" tables would have been to a student twenty years ago.

We can all probably be forgiven for taking electronics for granted – just as we take electric lighting, tap water and many other aspects of our daily lives in our stride, without so much as a second thought. The GCSE Electronics Syllabus requires the student to be aware of the impact and implications which this branch of technology might have on our lives, so by way of a break we give below some food for thought.

In 1953, a television cost £70 – say well over £1,000 in today's terms. It had a 9 inch (23cm) black and white tube, received one channel only and weighed half a ton (or so it seemed). Hopelessly inefficient, they conked out every few months.

Forty years later, a huge colour TV with teletext, stereo sound and remote controls costs about £500 or so. Inflation is responsible for *rising* prices, yet the cost of sophisticated electronics seems to *drop* even though the technology content leaps ahead! The following section highlights several areas which might help to view this important topic in perspective.

ADVANTAGES?

We summarise the main points whilst leaving you to expand on them as necessary. Firstly, what advantages do electronic systems have over, say, mechanical systems? Take the example of the wristwatch. Let's compare the digital watch against its traditional-looking analogue equivalent.

- ☑ A digital quartz controlled watch has a lot fewer moving parts – hardly any in fact – so they might be considerably more reliable.
- ☑ They are much cheaper to produce, especially using modern mass production techniques. A digital watch can be bought for £1.99 or less, and the watch "movement" could be cheaper than the strap! Thus accurate timekeeping is brought within the means of many more people and a digital watch might have far more features, e.g. an alarm or chronograph – or even a calculator! They could also be solar powered, needing no battery or winding.

Note that they tend to be thrown away if they develop a fault, because the cost of repair might exceed the value of the watch.

But on the other hand,

- ○ The introduction and popularity of the digital watch in the mid-late 1970's nearly ruined the Swiss watch industry.
- ○ The plummeting price of digital watches eventually forced them down-market, and after a while it became fashionable to sport a traditional *moving hands watch* instead – perhaps with a "moonphase" dial or other trimmings.

Check in a jeweller's shop window and you will probably see that the vast majority of watches are indeed moving hand analogue styles. The colourful Swatch is Swiss made and was an attempt to fight back against Far Eastern digital watches, but the watch industry can fall victim of prevailing fashions. However they will almost always use a quartz electronic movement inside – which are easy to mass-produce at very cheap prices.

ECONOMIES OF SCALE

Miniaturisation of electronic components, coupled with mass production techniques, brings about *economies of scale*. It costs roughly the same to run a factory in terms of manpower, insurance, rent, heating, lighting etc. (Fixed Costs) whether you produce one chip a day or a million. However if you can *raise the output* of a factory then although you are spending more overall on materials, power etc. (Variable Costs) then the actual *total* cost per unit will decrease, because you are spreading Fixed Costs over a much larger number of goods.

Couple this with the fact that you can obtain better buying prices when you buy in larger quantities, and this means that if you can make more items, then your cost of producing that item should come down. Thus it's more economical to *mass produce* components. However an economist will tell you that a watch, being an item of jewellery, might (like perfume) have a particularly *high* price to make it more desirable, as perceived by the consumer.

The introduction of automated electronic systems may have severe implications on traditional industries. In publishing for instance, it's now possible for journalists to type their work into a computer themselves, so there is less need to rely on typesetters and hot metal "linotype" operators. Computers can check the spelling, so a proof reader's services may be in less demand.

The result is a shift in emphasis towards the use of electronic systems away from mechanical methods, with accompanying job losses, plant closures and re-organisation. Conversely, the production of the publication becomes more efficient in terms of speed, man hours and cost, so the consumer benefits.

See if you can add to or expand on the following check list of "Pro's" which summarise the key benefits of electronics technology to society in general. One person's "pro" may be another's "con" – especially if you personally suffer loss of work as a result of the introduction of electronic systems. Try to relate to everyday life, rather than, say, military matters or other specialised areas.

Pro's of electronic applications

- ☑ Smaller, more energy efficient systems (pocket calculator, watches, computers).More reliability, increased operating life. (Car fuel injection systems vs. mechanical carburettors)
- ☑ Automated systems don't take tea breaks or go on holiday. Improved productivity.
- ☑ Improved accuracy and precision of processes (e.g. in the chemical or engineering industry, or civil works – surveying, bridge-building etc.)
- ☑ Electronics can fulfil some functions which would be difficult to handle with mechanical systems. (Environmental monitoring. Car radar traps.)
- ☑ More features than equivalent mechanical systems (e.g. 35mm compact camera).
- ☑ A lower cost, making the technology more accessible. (Personal Computers).
- ☑ Ability of solid-state systems to operate under extreme conditions (e.g. space or undersea exploration).
- ☑ Improved quality of human life – e.g. electronic aids for the disabled, advances in medical technology, electronic road/air/sea traffic surveillance and control, weather satellites, geophysical surveys.
- ☑ Less need for boring, repetitive or dangerous jobs to be performed by humans in manufacturing. (Production line work.)
- ☑ Improved communications – car phones, satellite systems, teletext, radar, electronic transfer of stocks and shares, banking, postal sorting, fax machines.
- ☑ A more aware and informed society (e.g. satellite pictures from Bosnia or Africa).
- ☑ Increases in productivity of humans due to the use of electronic systems to help in their work, e.g. word processing, spellchecking, computer aided design (the *Mini* and *Micro Labs*).

There is always a price to pay for everything, though, and the introduction of electronics might bring the following disadvantages with it:

Cons of electronics

- Obsolescence of systems caused by fast-moving technology (e.g. Personal Computers) – implies that it's expensive to keep up with the latest developments, but existing systems could eventually be rendered obsolete or unworkable. Result is a relentless demand for investment. The high cost to manufacturers to design the new technology.
- Effects of worker "obsolescence" – redundancy, replacement of humans with machines and electronic systems (e.g. robotics, factory work) – the need for redundancy pay, unemployment benefit, consequent bad debts caused by lack of income. More taxpayers' revenue required to pay for the support of unemployed persons. Less cash spent in shops or on goods when the local unemployment rate is high – reduced demand for merchandise.
- The need to train or retrain personnel in new cutting edge technologies – the "learning curve".
- Decimation of certain industries or skills with the advent of new technologies (Fleet Street).
- Expansion and encouragement of the "throwaway society" – the reduction in necessary repair skills. Leading to...
- The creation of waste materials caused by obsolete processes or equipment. The need for re-cycling.
- The requirement for much tighter security (encryption) techniques on e.g. computer records. The problem of "hacking."
- The potential invasion of personal privacy – computer "misinformation" transmitted to other agencies (e.g. maybe creating wrong consumer credit ratings for an individual), junk mail, bugging.
- Difficulty of understanding an electronic system just by looking at it (unlike, say, pneumatic or mechanical systems) – an esoteric technology not for the layman. A potential source of the "Luddite" effect.

If you are studying for GCE "A" Level, it's wise to build up a project folder at an early stage, snipping any newspaper or magazine articles which describe any *positive* or *negative* benefits from the application of electronics. Use the above check lists as a guide as to the sort of topics which would be relevant. Try to research the subject *yourself*, working on your own initiative studying current affairs rather than relying solely on in-class teaching.

With luck you might eventually take a more "global" view concerning the impact which electronic systems has had on our society. One thing is for sure – electronics researchers have more surprises to come in the years ahead.

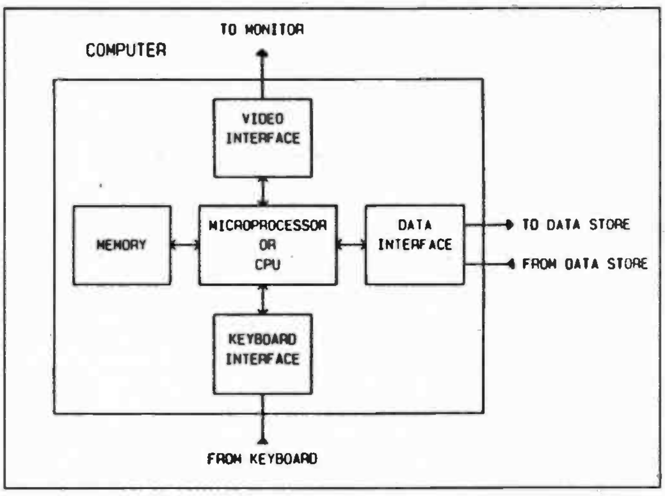


Fig. 9.2. Inside the computer.

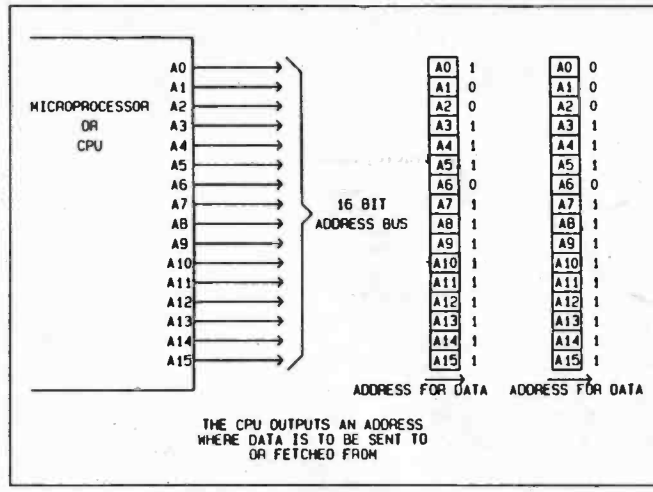


Fig. 9.3(b). Microprocessor address connections.

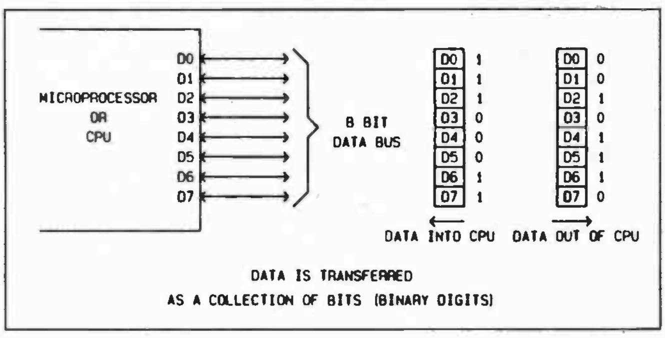


Fig. 9.3(a). Microprocessor data connections.

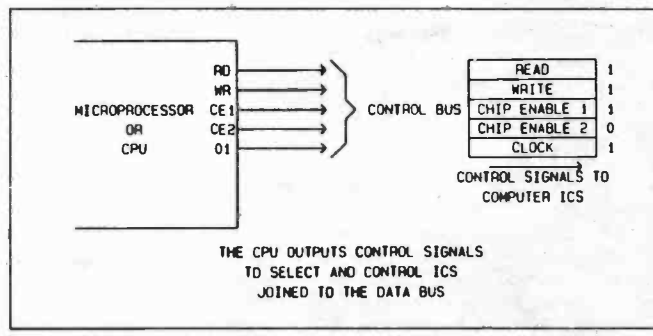


Fig. 9.3(c). Microprocessor control signals.

output to a black and white monitor, or a range of colour monitors.

The speed that the CPU can move data around the computer is the key to their success. Whilst we can write or type information at up to 100 words a minute, a computer could move millions of words in the same time. The CPU needs an efficient method of moving the data from one part of the system to another.

Instead of using a single wire between all the systems to send data over, most CPUs send data in parallel over lots of wires at the same time. Fig. 9.3(a) shows how the data is input and output from a microprocessor. In this example the CPU uses 8 parallel data connections to simultaneously transfer 8 bits of data. See the section on **Data Definitions**.

DATA BUS

A collection of data lines is called a **Data Bus.** Data can move into or out of the Microprocessor along the data bus, and we call this a *bidirectional* bus. Microprocessors can have different sizes of data buses, and in general the more data lines the faster data can be transferred around the computer. Personal computers started with 8 bit buses, but now have 16 bit and 32 bit buses. This is also true of computer games consoles. The faster systems now use 16 bit data buses.

Data lines carry binary signals at TTL levels. The first line is called D0 (Data 0) and the last in our diagram is D7. (With computers, the "first" number is actually zero and not one.) The data lines are joined to each i.c. in the computer. D0-D7 may go to many i.c.s that are all paralleled together.

ADDRESSES

The microprocessor has to have a means of determining which i.c. or peripheral the data is to be *read from* or *written to.* It does this by allocating an "address" for each piece of data it reads or writes. Fig. 9.3(b) shows a set of address lines from the microprocessor. In this case there are 16 address lines called an **Address Bus**. Usually the address bus operates in one direction. The CPU outputs "addresses" because it controls where the data is moved to.

The more address bus lines a CPU has, the more memory the CPU can address. For a computer with 16 address lines the maximum memory locations that it can send data to is 65,536. Refer to the section on **Hexadecimal Numbers** for a refresh on how binary numbers count. Some computers have many more address lines and can address over 4,000 million separate addresses.

Each i.c. attached to the data bus has its own address or range of addresses. This has an analogy to your postal address – the computer acts like the post office in delivering letters (data) to the correct location in the country (address). Some i.c.s (e.g. memories) have an address for each separate memory location. If we use the example of the *Micro Lab* computer this stores data and programs in a Static Random Access Memory (SRAM) with 32,768 locations, each able to store 8 bits (**1 byte**) of data. This takes up 32,768 locations or half the available *address map* (see later).

CONTROL BUS

The microprocessor now has a means of selecting where the data is to be sent, but it also has to tell the i.c. it is addressing whether it is reading or writing to that address. The Microprocessor uses special control signals to tell the i.c. what is expected of it. These control signals are called a **Control Bus**. There are no standards for the control signals as different microprocessors use different types of signal. Fig. 9.3(c) shows some of the control signals found on a typical CPU.

Two of the most common signals are the **Read** and **Write** lines. The CPU controls these signals to let the addressed i.c. know whether it has to *input* or *output* data to the data bus. Sometimes these signals are combined into a single line that is logic low when the CPU writes data, and logic high when the CPU reads data.

As the data bus is routed to all the i.c.s in the computer, then to select the correct address for each i.c., the address bus would also have to go to *each* i.c. This is acceptable in the case of the memory i.c. that uses 15 of the 16 available address lines to select the internal storage locations, see later. However, this becomes a problem where an i.c. occupies a single address location within the memory map. The i.c. would need a lot more pins than necessary, and subsequently cost more to manufacture.

To get around this microprocessors have

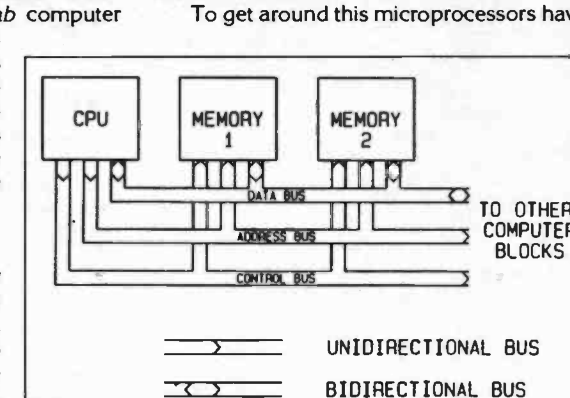


Fig. 9.4. CPU connections.

a means of decoding the address signals and issuing separate control signals to operate or *enable* the appropriate i.c. In the diagram these are shown as CE1 and CE2. This is an abbreviation of Chip Enable 1 and Chip Enable 2. The decoder may be a part of the microprocessor, or another separate i.c.. We will look again at this subject in next month's *Teach In.*

Another control signal commonly found in computer systems is a **system master clock**. This is used by some of the computer i.c.s to synchronise their internal operations to ensure that data is input or output at the correct time.

The control bus may contain other signals including **interrupt lines**. These are used by other i.c.s within the computer to interrupt the program it is using and make it run a more important task. More of this later.

CONNECTING UP THE MICROPROCESSOR

An illustration of how the CPU connects to other i.c.s in the computer is shown in Fig. 9.4. In this diagram we have just shown two memory i.c.s. The data lines go to each i.c. in the computer that need to read or write information. This method of interconnection is sometimes called a *daisy chain* as the signal lines loop from one i.c. to another in a ring. The address bus goes to each i.c., but only those addresses needed to operate the i.c. are connected. The control bus contains the read and write information along with the means to select the appropriate i.c. when it is to read or be written to.

This simple picture reveals a potential problem for the computer. As the data bus is *bidirectional* a method must be found to ensure that only one i.c. writes to the bus at any one time. Fig. 9.5(a) shows an 8 bit latch attached to the 8 data lines of the data bus.

The latch inputs have a high input impedance and present little loading to the data bus. Thus data bus can support lots of i.c.s with high input impedance without the signals becoming too loaded. Data is latched by the write line which is one of the control bus signals. All 8 data bits are latched at the same moment.

The latch outputs are connected to the data bus via **Tristate Buffers**. The outputs of all the buffers are turned on and off by the read line. Fig. 9.5(b) shows the mechanical equivalent for a tristate buffer. When the relay is turned on, or enabled, the input signals can pass to the output. When the relay is turned off, or disabled, the output will follow the voltage of other circuits it may be connected to.

The semiconductor version is a buffer with an enable input. When the outputs are turned on data can be written to the data bus as logic ones or logic zeros. When the outputs are turned off they have a high impedance and present no load to the data bus. In this state they follow the state of other data on the bus but don't interfere with that data. In this condition a tristate output is said to be floating. The tristate name comes from these three possible states – driven logic high, driven logic low, and floating.

MEMORY

The latch circuit shown in Fig. 9.5(a) forms a 1 x 8 bit memory. Data can be latched from the data bus for storage, and read onto the data bus when requested by the CPU. In a large scale memory many of these bistable latches are fabricated onto a single piece of silicon. The layout of part of a memory cell is shown in Fig. 9.6.

The line that controls whether data is read from or written to the memory is called the **Read/Not Write line** or **R/$\overline{\text{W}}$**. This is because when the line is driven to a logic 1 by the CPU this is seen by the memory as a Read command and the CPU can read data from the memory location "pointed at" by the current address. When the CPU pulls the line to a logic 0 the memory interprets this as a write command, and the data currently on the Data bus will be written into the memory location pointed to by the current address.

Because the write signal is a logic 0 it is called a Not Write command, and this is why the control line is called a Read/Not Write or R/$\overline{\text{W}}$. Some CPUs use two control lines for reading and writing to the peripherals. In this case either signal is valid when at a logic 0 level and are called active low signals.

The memory has internal logic to decode the control signals and address lines. Typical memory i.c.s used in computers may store 1 or 4 million bits of data. The complexity of the decode and interface buffers is hidden from the computer designer, who treats memory i.c.s as subsystems and uses them as building blocks in the design of a computer.

TRISTATE TRYOUT

It is possible to build a data latch and test its tristate output using a 74LS373 i.c. (Note a 74HCT373 is also acceptable in this application.). This contains 8 data latches with tristate outputs. There are two control signals that go to all 8 sections of the i.c. Fig. 9.7(a) shows 1/8 of a 74LS373 i.c. along with the enable control and output control signals. The table shows the effect of these two signals. Fig. 9.7(b) shows the pinouts for the 74LS373.

When the output control (pin 1) is low the state of the latch is output to the data output (pin 2 for this section). When the control pin is taken to a logic high the output is disconnected from the latch and presents a high impedance to other circuits it may be connected to.

When the enable signal (pin 11) is high the latch output follows the input signal. In this state the latch is called *transparent.* When the enable signal goes low the latch stores the logic level that was present on the input. When the output is enabled the stored value can be read.

Try connecting up this circuit on the *Mini Lab*, and test the action of the latch. We suggest that you use the two toggle switches for the output control and enable signals. Use a push switch with pull-up resistor for the data input. To test the

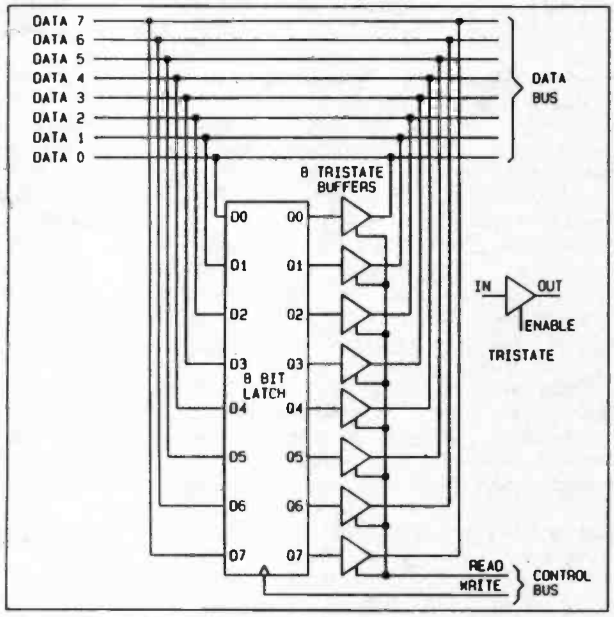


Fig. 9.5(a). Data latch with tristate outputs/

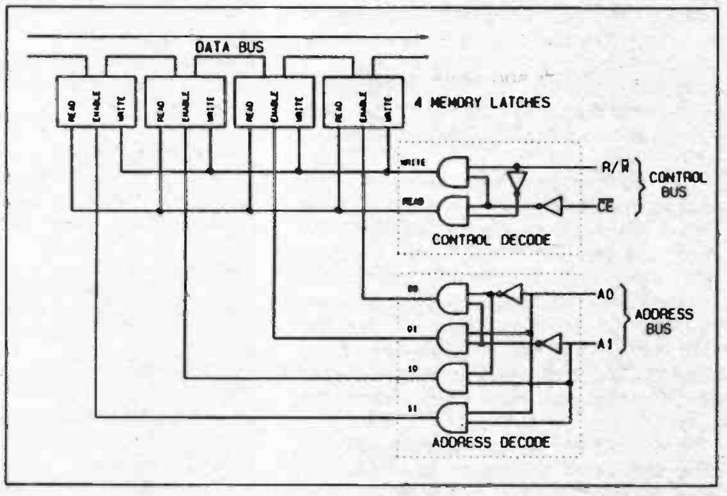


Fig. 9.6. A section of memory.

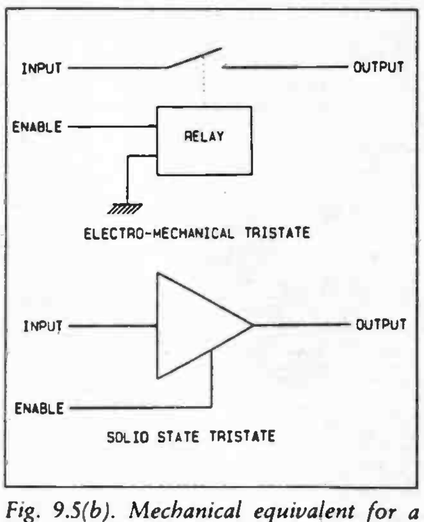
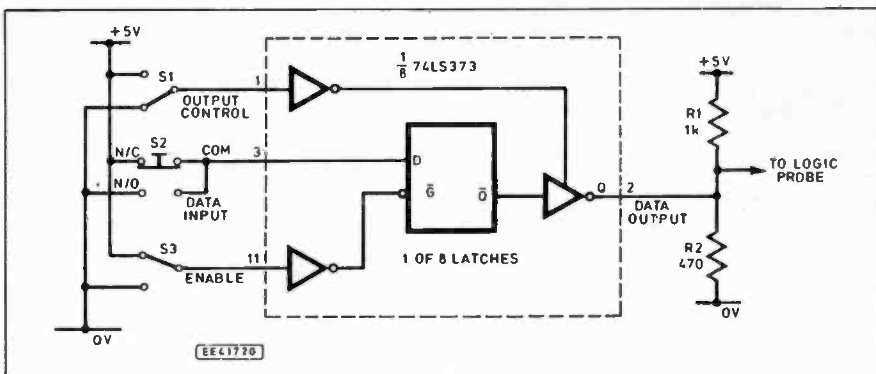


Fig. 9.5(b). Mechanical equivalent for a tristate buffer.



H = LOGIC HIGH (STEADY STATE)
L = LOGIC LOW (STEADY STATE)
X = DON'T CARE
Z = HIGH IMPEDANCE STATE
Q = THE LEVEL OF THE OUTPUT BEFORE ENABLE STABILISED

OUTPUT CONTROL	ENABLE G	0	OUTPUT
L	H	H	H
L	H	L	L
L	L	X	Q
H	X	X	Z

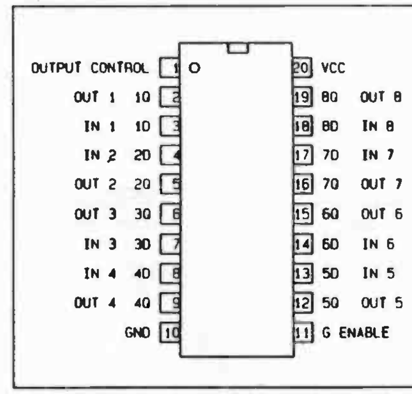


Fig. 9.7(b) (above). 74LS373 latch with tristate output pin connections.

Fig. 9.7(a) (left). 74LS373 Latch with tristate output.

tristate output we have used two resistors to load the output. The level of the output can be monitored with the logic probe.

Start by switching the '373 enable to low to latch the data, and the output control high to turn off the output. The resistors will act as a voltage divider and present the logic probe with 1.6 volts. This is an invalid state and will be indicated by both high and low l.e.d.s (D2 and D3) being illuminated. Take the output control low, and the resistors will be driven by the latch output to either a high or a low state depending on the data stored in the latch.

Turn the enable to high, and switch the data input alternately between high and low. This is the transparent state, and the logic probe will show the output follows the state of the input. While the data is high switch the enable low to latch the data. Now the data input can be changed without affecting the high stored in the latch. Similarly, store a low input into the latch. Again once the enable goes low the data input cannot affect the output.

At any time the output can be disabled to allow the output to float to 1.6 volts. The other 7 sections of the '373 latch will store data in the same way allowing 8 bits or 1 byte (see **Data Definitions**) to be stored. We have used the '373 latch on the *Micro Lab* to latch the state of the 8 input switches, and the CPU reads the stored value by controlling the tristate output.

A SMALL COMPUTER

We have looked at some of the subsystems that make up a computer, now let's see how they all join together. Fig 9.8 shows a complete computer system – in this case it is the *Micro Lab* computer, although many of the blocks will be used in most computer systems. This computer system uses 8 data bus and 16 address bus signals. This diagram has more detail and shows some new computer features.

The address bus is driven from the CPU and goes to every part of the computer. However, not all the address lines are required by each section. The LCD display, for example, only requires address 0 for writing data to the display. In Fig. 9.8, the number by each bus connection shows how many of the signals are needed by each subsystem. To reduce the number of address lines, the computer uses a special **Address Decoder**

HEXADECIMAL NUMBERS

When we looked at Binary numbers in Teach In it seemed to be the ideal way to consider digital numbers. Now we are considering microprocessors with 16 address lines the binary number system starts to look clumsy and it's confusing to clearly understand the value of a 16 bit binary pattern. Decimal is also confusing as the values represented by binary address lines increasing are not easily interpreted as 256, 512, 1024, etc. With 32 bit computers the numbers become too large to use easily. Consider the following table:

Decimal, Binary, and Hexadecimal Numbers

Decimal	Binary	Hexadecimal
0	0000 0000 0000 0000	0
1	0000 0000 0000 0001	1
2	0000 0000 0000 0010	2
3	0000 0000 0000 0011	3
4	0000 0000 0000 0100	4
5	0000 0000 0000 0101	5
6	0000 0000 0000 0110	6
7	0000 0000 0000 0111	7
8	0000 0000 0000 1000	8
9	0000 0000 0000 1001	9
10	0000 0000 0000 1010	A
11	0000 0000 0000 1011	B
12	0000 0000 0000 1100	C
13	0000 0000 0000 1101	D
14	0000 0000 0000 1110	E
15	0000 0000 0000 1111	F
16	0000 0000 0001 0000	10
17	0000 0000 0001 0001	11
18	0000 0000 0001 0010	12
161	0000 0000 1010 0011	00A3
255	0000 0000 1111 1111	00FF
256	0000 0001 0000 0000	0100
4095	0000 1111 1111 1111	0FFF
4096	0001 0000 0000 0000	1000
32767	0111 1111 1111 1111	7FFF
32768	1000 0000 0000 0000	8000
65535	1111 1111 1111 1111	FFFF
65536	1 0000 0000 0000 0000	10000

Hexadecimal numbers use a base of 16 to count by. Because we only have numbers in the English language to represent 0 to 9 the letters A, B, C, D, E, and F are used for 10, 11, 12, 13, 14, and 15. Thus each group of four binary bits can be represented with a single value. To indicate that we are using hexadecimal numbers they will always be followed by H. This is important when we need to know that CAFE is where we buy a coffee, whilst CAFE(H) means 51,966!

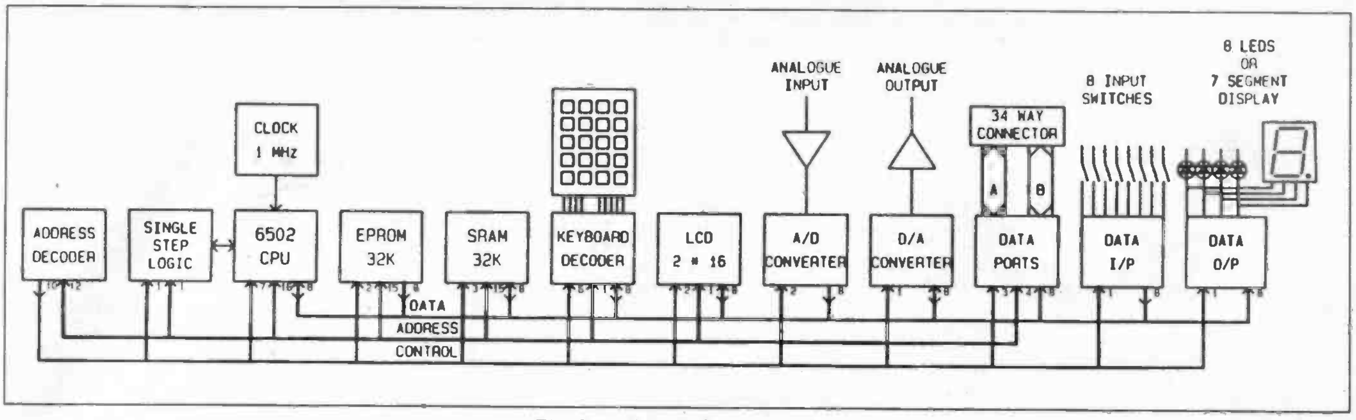


*Fig. 9.8.*Micro Lab *computer*

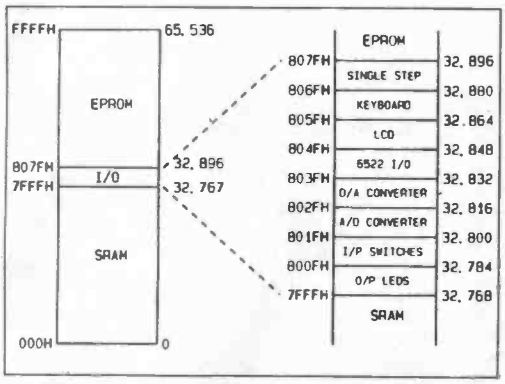


Fig. 9.9. Micro Lab *address map.*

circuit that produces control signals to select the various i.c.s. This saves having to use 16 address pins on all the i.c.s connected to the data bus.

ADDRESS MAP

All the devices that the microprocessor is able to read or write data to and from have their own unique space in the **Address Map**. Fig. 9.9 shows an typical address map – in this case it is for the *Micro Lab*. The address map is a plan of the computer's systems, and it shows the locations of all the subsystems connected to the data bus.

The memory locations are shown as both decimal and hexadecimal numbers. (See section on **Hexadecimal Numbers**.) The 16 address lines can address 65,536 or FFFF(H) locations. Don't worry too much about details of the map as we will look at this again when we start programming next month.

The **User Memory** comprises a single SRAM i.c. containing 265,144 memory locations organised as 32,768 × 8. This is called a 32Kbyte memory. (Note that computers use 1K = 1,024 bytes. A binary kilo – note the capital "K" to denote this.) The Program Memory is also stored in a 32Kbyte i.c., but this time it is an EPROM. Observant readers will now wonder where the Analogue to Digital (A/D), Digital to Analogue (D/A), and Input/Output (I/O) can fit as the whole 64Kbyte memory map is taken up with these two i.c.s.

This is where the **Address Decoder** is needed as it maps the physical location of the i.c.s connected to the CPU. In the *Micro Lab* the decoder is a single i.c., but the circuit function could be formed from a collection of TTL i.c.s. The decoder i.c. is connected to the address bus and is programmed to provide chip selects for all the i.c.s attached to the data bus. When the chips are not selected they are disconnected from the data bus by their tristate outputs.

The address map used for the *Micro Lab* shows that when the CPU needs to read from address 100(H) the only i.c. selected will be the SRAM. Similarly if the 6502 reads address E000(H) this will be from the EPROM. The A/D, D/A, l.c.d., and I/O "steal" some of the EPROM i.c. locations, which are never addressed. Storage i.c.s are so cheap that we can waste a small amount of an i.c. without feeling guilty!

TEACH-IN GCSE QUESTIONS

The following GCSE Qestion is reproduced with the kind permission of the Midland Examining Group, and appeared in their Electronics Paper 1 (1751/1) in June 1989. The answers are the work of the authors and may not constitute the only possible solution.

This is the last in the series of Questions we publish, and we thank all the GCSE Examining boards for their kind assistance and co-operation.

A small microprocessor system contains a CPU, an input port, an output port, and a ROM. They are connected to each other by the data and address buses as shown in the block diagram of Fig. 8.

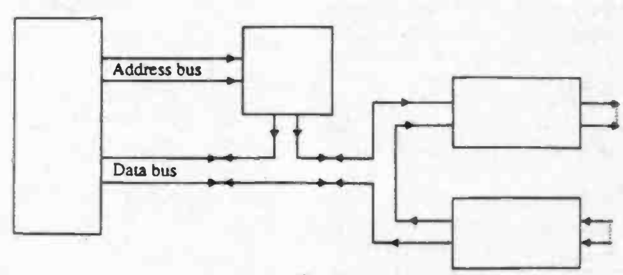


Fig. 8

(*a*) Label the four blocks of Fig. 8 to show which is the input port, the output port, the ROM and the CPU. [4]

(*b*) What is the purpose of the ROM in Fig. 8? [2]

....

....

(*c*) What is the purpose of the CPU in Fig. 8? [3]

....

....

....

Microprocessor systems like the one shown in Fig. 8 are general purpose digital systems. They can be made to behave like *any* digital system which has up to eight inputs and eight outputs.

(*d*) Explain what you have to do to the system of Fig. 8 to make it behave like a different digital system. [2]

....

....

(*e*) State two commercial advantages of using a microprocessor rather than logic gates to make a large digital system. [2]

1 ....

....

2 ....

....

COMPUTER MEMORY TECHNOLOGIES

Whilst computers are relatively young in historical terms the developments in semiconductor technology have been phenomenal. As the silicon fabrication plants get ever more sophisticated new techniques continually emerge for the storage of data associated with computers. The memory terms used are:

Volatile Memory can lose the stored information if the power is removed from the i.c.

Nonvolatile Memory retains its data when the power is removed from the i.c.

Random Access Memory or **RAM**. This is the term used for computer memory. It describes memory in which any address can be read or written to in any order. Early memories had to be read in sequence which slowed the rate of data access.

Read Only Memory or **ROM**. This is the term used for memory that the computer can only read. Due to the technologies used the computer cannot reprogram the stored information. This is where computer operating programs are stored.

Dynamic Random Access Memory or **DRAM**. This is the dominant type of memory used in personal computers due to the lowest cost/bit currently available. DRAM is a volatile memory, and removal of the power causes the contents to be lost. Each memory cell relies on stored charge in a capacitor to hold a data bit. The DRAM devices have to be constantly "refreshed" to retain the stored charge in the capacitor. This is usually carried out automatically by special DRAM controller i.c.s. Some microprocessors (but not the 6502) have this refresh function designed into them. Each storage cell only uses a single transistor, and many bits can be put on a single piece of silicon. Currently the biggest devices are on sale can store 16Mbits of data.

Static Random Access Memory or **SRAM**. The current SRAMs use two transistors per bit to store data, but don't need continuously refreshing to keep the data. This makes them suitable for battery back-up circuits where a small current is needed to retain the contents of a whole i.c. As the construction uses a greater area of silicon the largest devices on the market store 4Mbits of data. The SRAM used on the *Micro Lab* stores 32,768 bits and will retain this with voltages down to 2.5 volts and 10μA of supply current. This memory may be accessed quicker than DRAM.

Erasable Programmable Read Only Memory or **EPROM**. These memories are used to hold computer data in a near permanent manner. The devices are usually programmed in special programmers by using higher voltages to shake electrons through barrier layers. Once programmed the memory is retained in the absence of power for at least 10 years.

EPROMs can be erased by exposing them to ultraviolet light of a particular frequency. This shakes all the electrons back through the barrier and erases the i.c. Sunlight contains small amounts of this range of UV and exposure to direct sunlight will eventually erase an EPROM. For this reason the window in the case is covered over by a label. The EPROM supplied with the Micro Lab has 32,768 data bits, but is small compared to the 4Mbyte devices currently on sale.

Electrically Erasable and Programmable Read Only Memory or **EEPROM**. These devices are similar to EPROMs in operation, but the contents can be erased electrically. This means that the chips can be bulk erased in circuit and reprogrammed without having to open the equipment case. An example of this type of use is the ticket machines in British Rail stations. Overnight new fare tariffs can be down loaded via data links over telephone lines. EEPROMs are made of a number of different technologies.

The type that may become dominant in the future is **FLASH** memory. These have a small cell structure and are becoming cheaper to produce each year. The largest devices on the market are 8Mbit types. These will find many applications as solid state storage, but are unlikely to replace computer disk drives in the near future. Their advantage of being a rugged storage medium is offset by the longer write and erase time compared to their hard disk rivals. However, the market for memory cards is growing phenomenally, and this is where FLASH memory will make its mark.

Magnetic Data Storage – Disk Drives. This technology relies on thin films of magnetic material coated onto ultra smooth disks. Hard disks rely on non flexible disks, and are usually sealed to stop the ingress of dust. Data is stored on the disks magnetically via read/write heads which "fly" a few microns above the disk surface.

When every new generation of silicon storage device seems to threaten the existence of the computer disk, the disk manufacturers respond by producing ever smaller drives containing larger amounts of data. 10 years ago a hard disk drive was too expensive for the new personal computers, and they made do with 360Kbyte floppy disks. Now there are hard disks small enough to be mounted on a computer memory card that can store over 50Mbytes of data.

PAL

The decoder i.c. used in the *Micro Lab* is specially setup for the board design. It uses a combination of logic elements that are joined together internally. A design program is used to configure internal links on the inputs and outputs to make the required circuit functions. This type of i.c. is called a **Programmable Array Logic** or **PAL**. Because a special programmer is needed to configure the i.c. the decoder is supplied preprogrammed.

In the *Micro Lab* computer there are some i.c.s that need a $R/\overline{W}$ signal and some that need a separate RD and WR lines. The 6502 CPU only generates a single $R/\overline{W}$ and this has to be further decoded with the clock signal to produce the required RD and WR control signals. Most computers have additional logic like this to match the subsystems to the CPU control requirements.

Most i.c.s in a computer system have active low control lines. The names for the lines are often abbreviated and active low signals are shown with a line over the abbreviation in a similar way to Boolean logic. Memories use two active low control signals. The first is a Chip Enable ($\overline{CE}$), and second is called the Output Enable ($\overline{OE}$).

Consider the amount of storage bits we have with the *Micro Lab*. The 32Kbyte SRAM has 256,144 data latches on the i.c.. This is a small memory by todays standards. Most personal computers use DRAM for their memory storage as this type of memory is cheaper to produce.

The manufacturers of memory i.c.s are now selling 16Mbit devices and 64 Mbit devices have been prototyped! These represent the leading edge of silicon development as the commercial rewards from being first to market these devices is considerable.

Look again at Fig. 9.8 and try to identify whether the blocks are input or output data to the CPU. Notice that the EPROM only outputs data, whilst the SRAM is bidirectional. The data I/P, data O/P, D/A, and A/D are unidirectional, whilst the data port is bidirectional.

The keyboard decoder and Liquid Crystal Display (l.c.d.) are also bidirectional although they only input key presses or output display characters. These subsystems are more complex and can work in a number of different ways. The microprocessor has to initialise them to operate correctly by reading and writing to control latches. Once this is done the keyboard becomes an input device, and the l.c.d. an output device.

CPU OPERATION

Now we have looked at how some of the peripherals are joined to the address and data bus, how does the CPU control their operation? A collection of these circuits seems a long way from the power of a games console that moves colour images around at high speed. We need to look at the heart of the CPU to understand how it controls and manipulates data. Fig. 9.10 shows some of the internal circuit blocks of a microprocessor. Don't worry if this looks complex as we will cover the sections again as we learn some programming commands. Let's take a look at the main parts of the circuit.

The **Clock Generator** uses an external TTL clock to operate the CPU. Most microprocessors have clock generating circuits to buffer the incoming TTL signal and produce timing clocks. In this CPU there are two clock signals 01 and 02, which are out of phase with each other. Both are used for the internal timing of the CPU

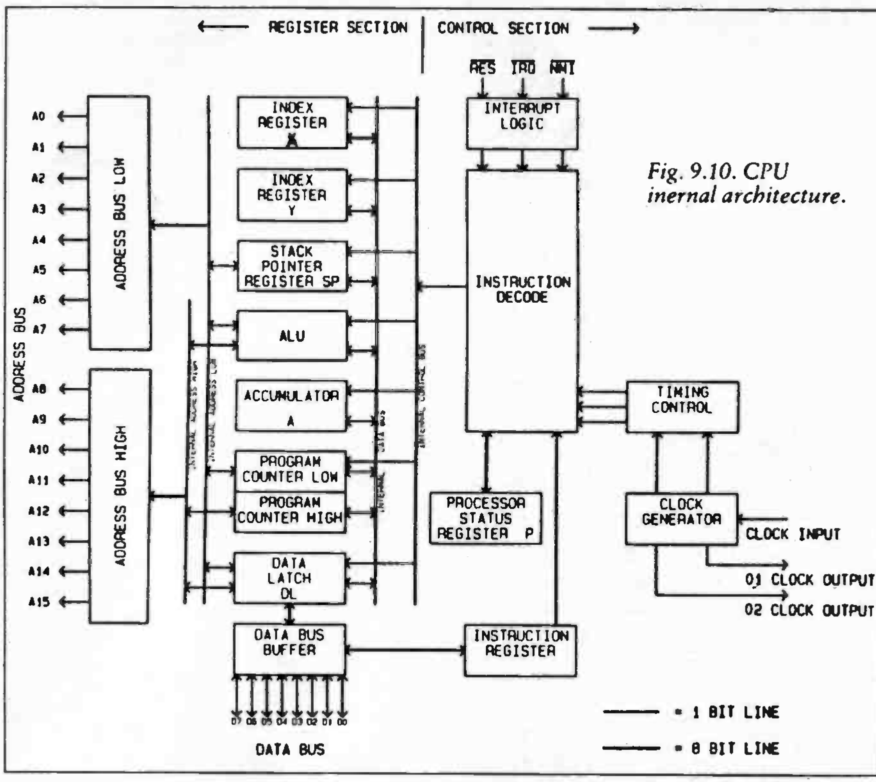


Fig. 9.10. CPU inernal architecture.

circuits, and they are both made available for use by circuit designers. The *Micro Lab* makes use of both clocks for producing the signals that control the peripheral i.c.s.

The *Micro Lab* 6502 CPU runs from a 1MHz master clock. There are faster 6502 i.c.s available that will run with a 3MHz clock, but we don't need the extra speed for our experiments. If you buy a faster grade CPU designed to run with a 2MHz or 3MHz clock it will work quite happily with our 1MHz clock.

Computer clocks are produced from an oscillator circuit based around a quartz crystal. This provides the stable frequency input needed by the microprocessor to time all the data transfer operations. A typical crystal oscillator is made from a number of inverters with the quartz crystal connected in the feedback loop to fix the frequency. Fig. 9.11 shows the oscillator used in the *Micro Lab*.

We used a 2MHz crystal for the oscillator and divided the output with IC8 down to 1MHz. This has two benefits over using a 1MHz crystal. The first is the greater accuracy of the clock produced this way. The output of the 2MHz oscillator has an uneven mark to space ratio, but by dividing the signal by two the resulting 1 MHz frequency has a symmetrical wave shape with 50 per cent duty cycle. (Most personal computers use a higher speed crystal for the CPU in this way. A 25MHz 386 will use a 50MHz crystal.)

The second advantage of clock dividing for the *Micro Lab* is cost reduction. Look in a catalogue at the price of 1 and 2MHz crystals. The price difference in switching to 2MHz more than pays the extra cost of the divider IC8 (and this doesn't allow for the use of the second half of the divider as a latch for the single step circuit to be described next month.)

MICROPROCESSOR ARCHITECTURE

There are a number of latches inside a microprocessor called **Registers**. Microprocessors can have various sizes and types of registers – the more powerful devices used in personal computers have lots of 32 bit wide registers. The 6502 microprocessor used in the *Micro Lab* is typical of small CPUs and all but one register are 8 bits wide. The **Program Counter** is the only 16 bit register.

The Program Counter is a 16 bit counter that contains the location of the current address that the CPU will read data from or write data to. The counter is incremented after each read instruction operation.

The program counter is split into two halves. The lower outputs the first 8 address bits, and the upper outputs the second 8 address bits. The lower 8 address lines can decode 256 memory locations from 0 to 255. Some of the CPU instructions only use the lower 8 address bits, and these are faster.

The **Data Latch** is a bidirectional latch for reading and writing data onto the data bus. The signals are buffered to drive all the peripheral i.c.s via the **Data Bus Buffer**. The CPU has a separate internal data bus to allow data to be transferred between its internal registers.

REGISTERS

The three most important registers from a programming point of view are the X Register, the Y Register, and the Accumulator. In the 6502 these are all 8 bit bistable latches or flipflops.

The **Accumulator** is the main register of the CPU. When instructions are processed by the CPU the accumulator will often be involved in the execution of that instruction. The accumulator is an 8 bit register that stores the results of most arithmetic and logic operations.

The accumulator is closely linked to the **Arithmetic Logic Unit** or **ALU**. All arithmetic and logic operations take place in the ALU. For our introduction to programming we will be able to ignore the fine details of what goes on in the ALU, and concentrate on moving data around the system.

There are two **Index Registers** called **X** and **Y**. The index registers may be used to count program steps, or to provide an index value to be used in generating an address for the next program instruction. They can also be used to store information that may be needed frequently by the CPU as it runs a program. Both the **X register** and **Y register** are 8 bits or 1 byte wide. We will take a look at these index registers in future sections where their operation will become clearer with demonstration programs.

The 8 bit **Status Register** contains seven status flags. It operates all seven flags separately, and uses them to store the current situation within the CPU. As an example one of the status register flags is used to indicate whether an accumulator operation produced a negative result. This is called the **Negative Flag**. We will look at the other flags when we start running short programs.

INTERRUPT

The **Interrupt Logic** allows external signals to interrupt the current CPU operations and run another program. There are three interrupts on the 6502, and each has a different effect on the operation of the CPU.

The **Reset** input is used to start the CPU from a power down state, or a restart condition. Any information contained in the registers is lost after a reset, and the CPU restarts its operating program from a defined location. The *Micro Lab* has a reset button, and this will be used to restart the CPU if a program you have written appears not to be working correctly.

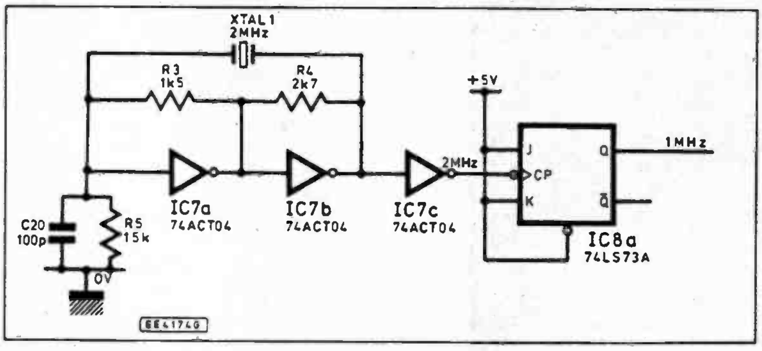


Fig. 9.11. Microprocessor clock.

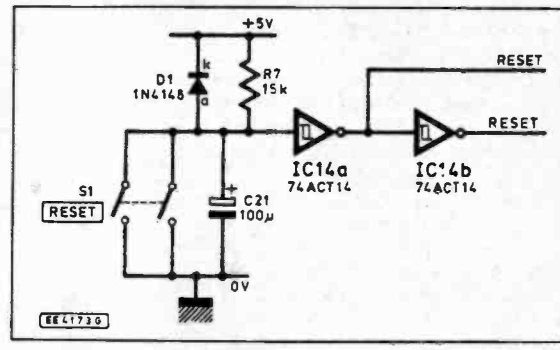


Fig. 9.12. Reset circuit.

GCSE QUESTION ANSWERS

(a) Left to right, clockwise: CPU, ROM, Output, Input.

(b) The ROM holds the program together with constant data.

(c) The CPU reads data from the input, processes it according to the program held in ROM and sends the result to the output.

(d) You have to re-program the ROM so that the CPU can perform a new function.

(e) 1. It's reprogrammable so that the same basic microprocessor system can be made to perform different functions

2. Error correction/program modification is cheaper on a microprocessor system rather than redesigning or scrapping a complex system using separate gates.

The **Interrupt Request** input signals to the microprocessor that an external device would like to interrupt the current program. This is a very civilised approach to interrupting the current program as the CPU can decline to accept the interruption. When an interrupt request is detected the CPU will finish the current program instruction and then check the state of the interrupt flag in the status register. If the current program has set the interrupt flag to zero then the interrupt request will be ignored. If the flag is set to a one then the interrupt can be accepted, and a new task run. At the end of the new task the CPU resumes the program it was running.

The **Non Maskable Interrupt** is an *unconditional* interrupt. The CPU will finish its current instruction, and then it will have to follow the new program regardless of the state of the interrupt flag. Again once the interrupt program has finished running the CPU can resume the program it was currently running.

The **Stack Pointer** or **Stack** is used by the CPU for the following:

- *To keep a record of where to resume a program if it has been forced to run another task. This could happen if the CPU received an external interrupt signal.*
- *To keep a record of where to resume a program when a sub-proceedure is called*
- *To temporarily store data*

COMPUTER INITIALISATION

All of the above has probably left you reeling from all the new terminology. As we move forward with the series we will cover all the sections again, and illustrate their functions with demonstration programs. For those who want to get hands on experience with the *Micro Lab* now is the time to look at the constructional section. We think it will take you a while to build the *Micro Lab*, but once complete it will be used for all the practical work in the next months.

If you have completed the construction and powered up the *Micro Lab* you should have been rewarded with some lines of text on the l.c.d. display. Let's look at what happens within the *Micro Lab* to make the text appear on the display.

All computer systems need a **Reset Pulse** to start them operating correctly. Fig. 9.12 shows the *Micro Lab* reset circuit. This fairly simple circuit provides the reset pulse to the CPU and some of the other i.c.s. When power is first applied to the circuit C21 is initially discharged, and pin 5 of IC14 is at 0 volts. IC14 is a 74LS14 hex inverter with Schmitt trigger inputs. The output of this inverter at pin 6 is high. This is the RESET output. This is inverted to produce a logic low at the $\overline{\text{RESET}}$ output on pin 8.

As capacitor C21 charges through R7 towards +5 volts it will pass the Schmitt threshold voltage and the RESET line will go low. Similarly the $\overline{\text{RESET}}$ output will go high. With the RC values used the reset period is approximately 0.5 seconds.

When the *Micro Lab* is turned off the capacitor can discharge via D1. A manual s.p.n.o. switch S1 across C21 allows the user to manually initiate a reset pulse by discharging C21 while the *Micro Lab* is powered.

The RESET signal goes to pin 40 of the 6502, the RESET input. The data sheet for the 6502 says that the CPU clock must be present for a minimum of 6 clock cycles before the reset is released. In practice we have allowed a much greater time for the external circuits to stabilise before resetting the processor.

RESET SEQUENCE

After the 6502 RESET goes high the interrupt flag is set high and the microprocessor loads its first instructions from address locations FFFC(H) and FFFD(H). This is the start location for all 6502 programs. All microprocessors have a built in address location where they will look for the first line of an operating program. Sometimes this location is at the bottom of the memory map, and the EPROM would be mapped there by the address decoder.

If you check the memory map in Fig. 9.9 you will see that FFFC(H) and FFFD(H) are near the top of the EPROM, and this location does indeed contain the first lines of our monitor program. The first few lines of our program are instructions to the CPU to initialise the stack register and check whether the memory has been corrupted or preserved by battery or +5 volts.

If the memory is corrupted the program sets all the RAM to 0. The program then initialises the input and output i.c.s on the board to the correct state by sending data to their internal registers. This routine is called Basic Input/Output Operating System or BIOS. After this is complete the message:

BIOS Loaded

comes up on the top line of the l.c.d. The program then initialises the Operating System or OS by setting up an area of memory. When this is complete the message:

BIOS Loaded
O/S Loaded

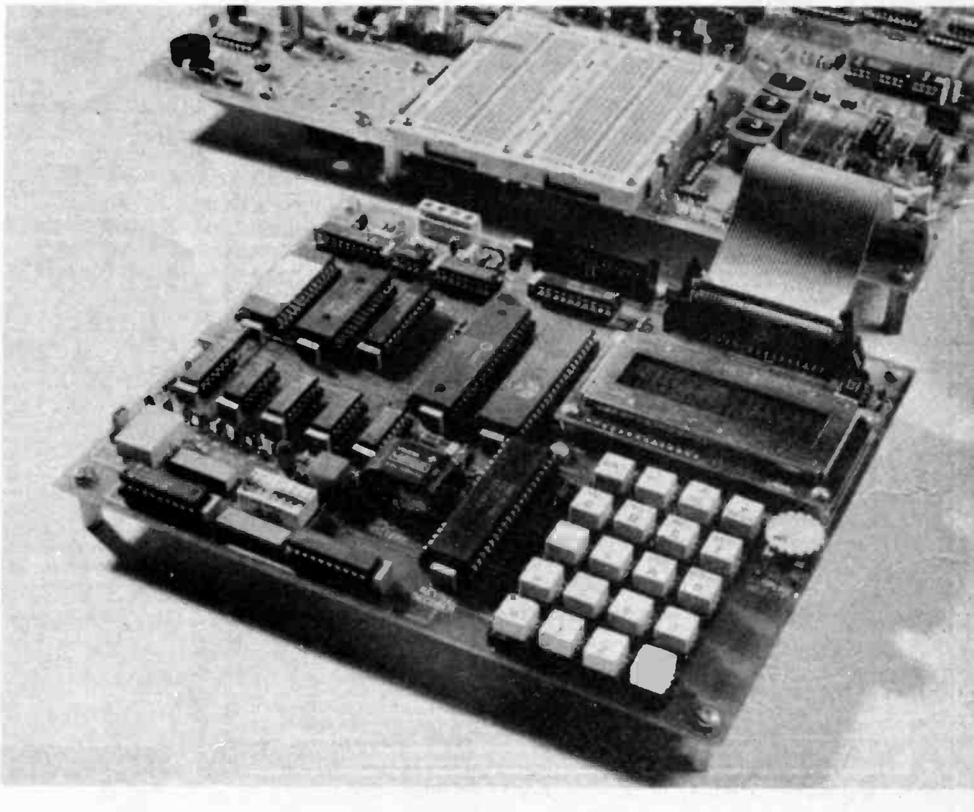
is written to the second line of the LCD. The program then starts the monitor by sending:

O/S Loaded
Micro Lab V1.00

to the l.c.d. At this point the display scrolls and the first line is lost. The initialisation routine is now completed by presenting the cursor ready for you to input your commands, and the display looks like this:

Micro Lab V1.00
>_

We will start writing programs next month using the *Teach-In Micro Lab* for the practical demonstrations. Its your chance to be in control!



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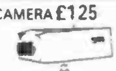

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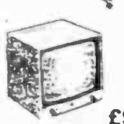

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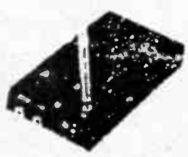

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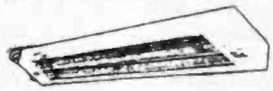

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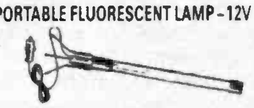

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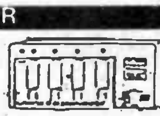

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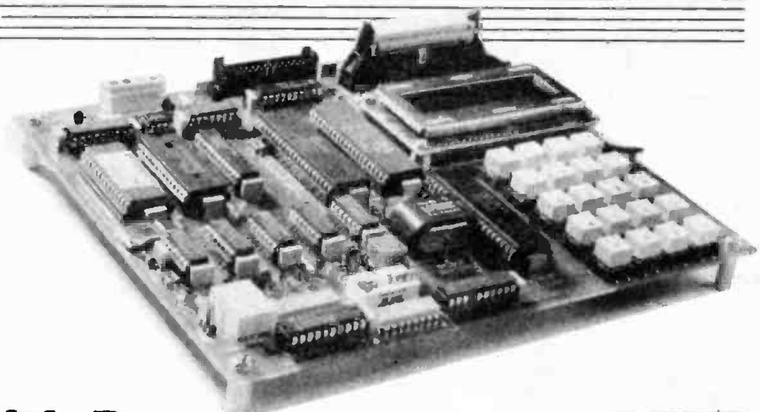


MICRO LAB

Alan Winstanley & Keith Dye B.Eng(Tech)AMIEE

The Everyday with Practical Electronics Micro Lab has been created to accompany Teach-In '93, it can form the heart of many control, experimental and measurement systems and has ten built-in demonstration programs

YOUR *Micro Lab* has been specially commissioned for Teach-In and is a sophisticated microprocessor training and applications unit. It can form the heart of many control, experimental and measurement systems, being capable of on-board analogue-to-digital (A/D) conversion and D/A as well.

CLIMB ABOARD!

Both the *Micro Lab* and the text are designed for more advanced readers rather than the absolute beginner; nonetheless we expect many readers will be able to assemble the *Micro Lab* first, and then subsequently use it to follow Teach-In and then learn how the *Micro Lab* operates.

Subsequently you will be able to program the *Micro Lab* and run your own routines, using it as a very versatile control or measurement system, or experiment with it in other ways. Teach-In describes the fundamental concepts of microprocessors to support those undertaking GCE "A" Level Electronics studies, exceeding the requirements for GCSE. We hope *Micro Lab* will also appeal to those looking for a general purpose microprocessor control unit, perhaps dedicated to a particular application.

Microprocessor technology is very sophisticated and we have tried to maintain the appeal of Teach-In by considering fundamental principles only, without becoming too deeply involved with fine detail. The *Micro Lab User's Manual* is supplied with the p.c.b. and contains a complete circuit diagram, detailed program listings, the 6502 "instruction set" and additional information.

This article concentrates on the practical assembly aspect of the design. *Micro Lab* uses a well-established central processor unit (c.p.u.) chip – the 6502 – but with some modern peripheral devices to form a really versatile design. Refer to "Micro Lab Technical Specification" for a run-down of key features.

Power for the *Micro Lab* comes from the *Mini Lab* 5V rail which is connected by a ribbon cable. A screw-terminal block provides a method of running the *Micro Lab* from a *separate* 5V power supply instead of that provided by the *Mini Lab* p.s.u. However this connection is not

MICRO LAB TECHNICAL SPECIFICATION

Specification:

Microprocessor:	8 bit 6502
Clock Speed:	1 MHz
RAM:	32Kb with battery backup
EPROM:	32Kb
Analogue Input:	0 to 2·5V Accurate to 0·01V
Analogue Output:	0 to 2·5V Accurate to 0·01V
Displays:	2 lines by 16 character l.c.d. variable contrast
	7 segment l.e.d.
	8 data l.e.d.s
Keyboard:	20 key, interrupt driven + reset
	8 DIP switch inputs
Input/Output ports	6522 VIA providing:
	16 individually programmable I/O
	4 control lines
	Serial output
	Hardware pulse counting

Micro Lab Monitor:

The monitor provides the following facilities:
- Entering and editing user programs
- Running user programs
- Single step through programs with register display after each instruction
- Break into user programs with register display
- Microprocessor register editing

Routines which may be called by user programs to perform the following:
- Display output routines, including cursor control, hex. and string output
- Keyboard input and control routines, including hex. input
- Sound output routines

Ten demonstration programs:
- Sequenced output to data l.e.d.s
- Programming a 7 segment l.e.d.
- Digital input using DIP switches
- Analogue input
- Temperature control
- Data logging
- Voltage to frequency conversion
- Playing a programmable tune
- Sound sample recorder
- Sound sample player

Micro Lab hardware development: Keith Dye B.Eng (Tech.) AMIEE

Micro Lab Monitor Program written by Geoff MacDonald B.Sc (Hons.) AMIEE

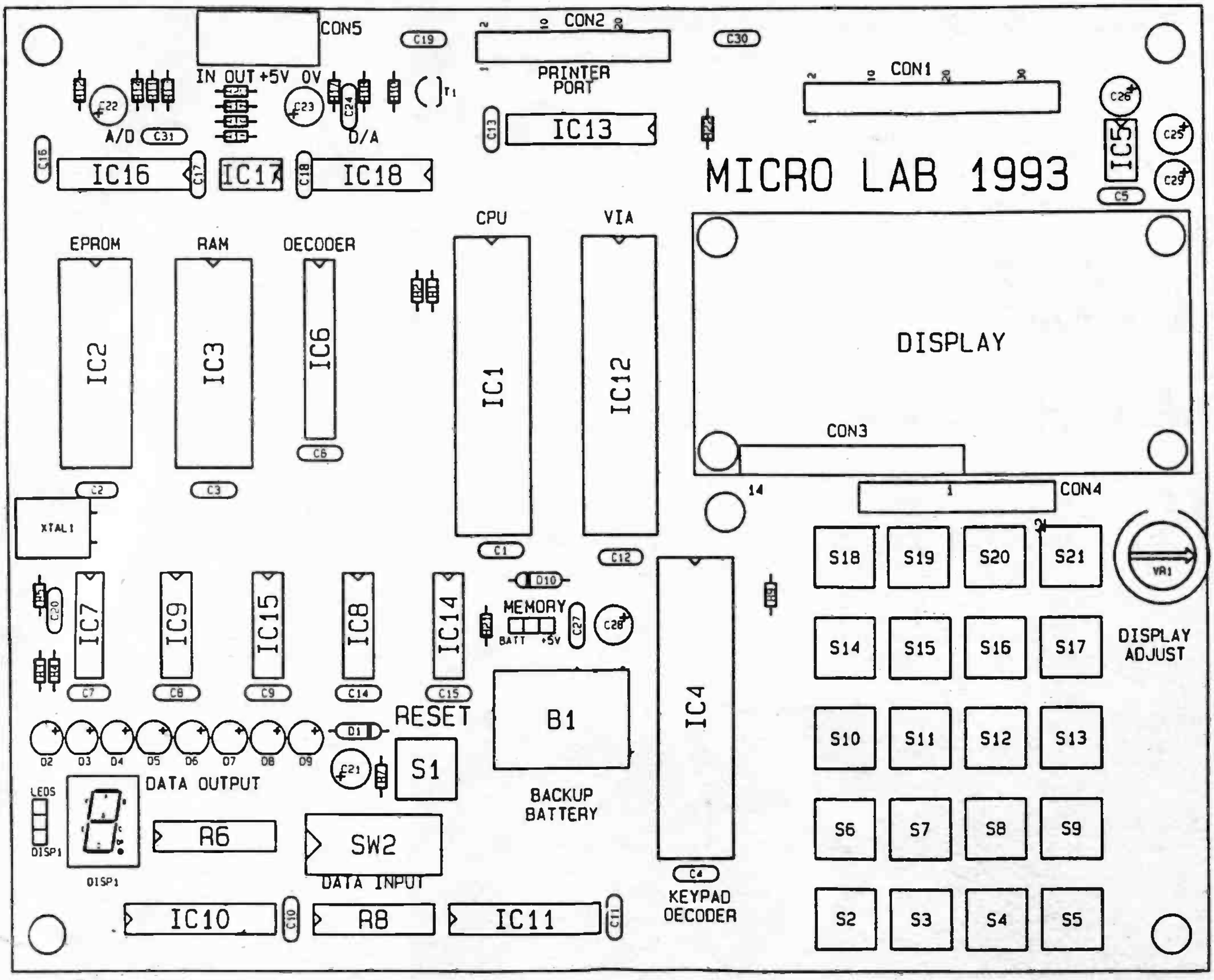


Fig. 1 Micro Lab *component layout*

reverse polarity protected and **SERIOUS DAMAGE** may result if you connect an external 5V power supply the wrong way round – **For experienced constructors only!** The four-way terminal block also accesses an analogue IN and analogue OUT port (each with respect to the 0V rail).

Soon, it will be possible to list program routines on a printer through the optional printer port which will be Centronics compatible and use a BBC Micro type printer lead. *Micro Lab* can read 32Kb "EPROM" memory chips containing custom-written programs, and has 32Kb of SRAM on board, protected by a rechargeable Ni-Cad back-up battery. Furthermore, a specially written "monitor" EPROM chip contains a sequence of instructions which enables users to either run one of the built-in applications, or program the *Micro Lab* themselves. This EPROM chip is supplied with the board.

BEFORE YOU START

The *Micro Lab* board is a precision design, manufactured to close tolerances. First, **it is absolutely essential that the constructor uses a micro fine-tipped low power soldering** iron neatly and skilfully if the *Micro Lab* is to be assembled successfully. Buy a special tip if necessary – say 1mm diameter or less – with say a 15W iron, preferably temperature controlled/ thermostatic in action. Use *fine gauge* rosin-core solder as usual, too.

Do not overheat the copper pads of the p.c.b. or you will lift them off the board and damage it irreparably. Well under one second per joint should be about right generally – very slightly longer with larger joints. Take the greatest of care when applying heat and there should be no reason why the *Micro Lab* shouldn't work first time – our prototypes did!

The *Micro Lab* p.c.b. has tracks *both* sides, protected by a green solder resist. Often tracks connect through to the other side using **plated-through hole** (PTH) technology – tiny silver-colour holes in the board. PTH pads are not to be interfered with in any way! **Do not solder them, even though they look like solder pads.**

The p.c.b. is fully silk screen printed on the surface to permit precise component positioning. The board, being of a compact nature, will not withstand heavy desoldering so make certain you position all parts correctly before committing to solder.

Please note, we have taken great care in compiling and cross-referring the lengthy Parts List. Follow it closely and check with all the usual sources of components to ensure the correct components are acquired. Any critical information is given in *Shop Talk* as always. Please read that too. If necessary, compare dimensions and pin-outs against your *Micro Lab* p.c.b. before purchasing individual parts.

INTO ACTION

The component side of the board is shown in Fig. 1. Start with the integrated circuit sockets, preferably using turned-pin types if affordable. (You could instead use s.i.l. sockets throughout, cut to length as needed.) The socket for the decoder chip is *non-standard*: use a **0.3 inch wide** 24-way socket, or alternatively both a *standard* 16-way and an 8-way socket, butted up to each other to form 24 ways.

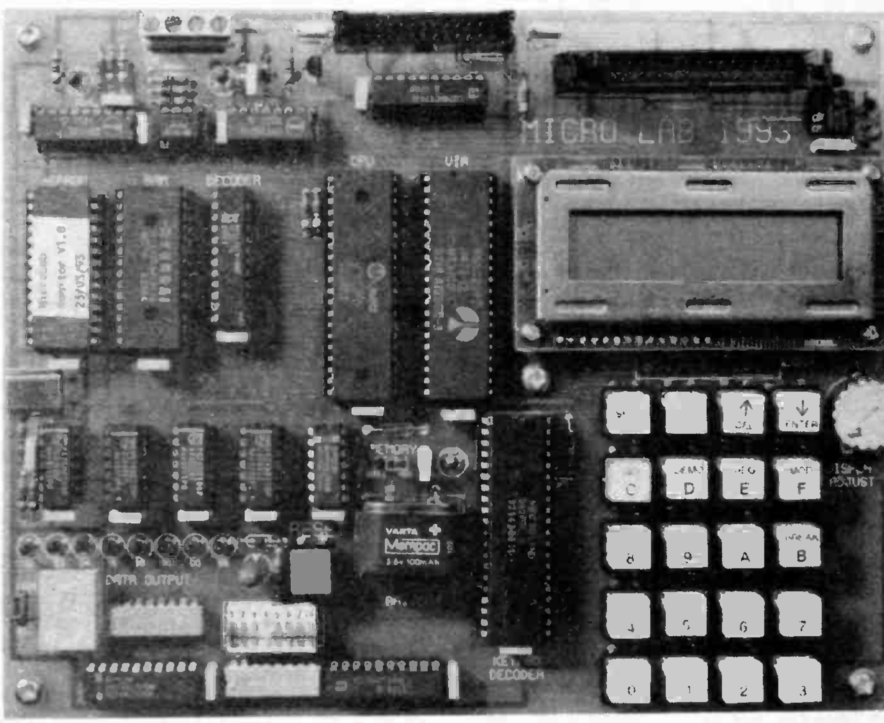
For the EPROM socket, use a standard 28-way d.i.l. socket, preferably a *low* insertion force type. This prevents wear and tear to the board when exchanging EPROM chips. Do not use a ZIF (zero insertion force) socket because it will not fit the p.c.b. The other sockets are standard, including some 40-way d.i.l. monsters!

Make sure all sockets are flush against the board before soldering – tape them down firmly with sticky tape if needed. **Do not install any i.c. devices at all just yet** - keep them all in their anti-static packaging for now.

Next, insert all discrete components – the resistors and capacitors. Following a modification, one "resistor" R20 is now a simple wire jumper link. Tantalum bead capacitors are used in several locations, so observe polarity as usual. All component leads are best snipped to length **before** soldering, to avoid damaging the p.c.b. tracks through mechanical shock.

Follow on with the light-emitting diode display (D2 to D9) and the 0.56 inch seven-segment display. The silk screen print clearly shows the correct orientation. Continue with the "d.i.p." switch package

PART REF.	FUNCTION	NOTES
IC1	6502 CPU	The microprocessor (CPU) at the heart of the Micro Lab
IC2	EEPROM	Memory i.c. containing operating/ demo monitor programs
IC3	SRAM	Static RAM Memory used by the CPU to store data
IC4	Keypad I.c.	Keyboard-to-CPU interface/ controller
IC5	-5V generator	Negative 5V rail generator for A/D & D/A buffer op-amps
IC6	Decoder	Programmable Logic Device (PLD) containing memory map of the Micro Lab
IC7	Logic	3 gates form a 2MHz clock, others control signal generation
IC8	Dual flip flop	Clock divider, latch
IC9	Logic	Control signal generation
IC10	Data Latch	Latches data from Data Bus, drives l.e.d. output display
IC11	Data Buffer	Tristate output, Octal data buffer interfaces dil switches to the Data Bus
IC12	VIA	Versatile Interface Adaptor for Input/ output & printer port control
IC13	Data Buffer	Buffers the VIA signals when printer port is in use
IC14, 15	Logic	Control signals generation
IC16	A/D	Analogue to digital converter, input 0 - 2V5 max.
IC17	Dual op-amps	Buffers A/D input and D/A output
IC18	D/A	Digital to Analogue converter, output 0 - 2V5 max.



(DATA INPUT) and the dual-in-line resistor networks (two off). Two s.i.l. pin headers are needed (DISP selection and BACKUP MEMORY selection) – fit them next.

Solder in all remaining discrete components including the Schottky diode, leaving the l.c.d., keypad and battery back-up until last. The components centred around the PRINTER PORT are omitted for now – they are not shown in the Parts List, and this section is to be described in the near future.

KEYPAD

Twenty-one key switches (including the reset) are needed, and needless to say, only the approved types should be used which match the p.c.b., see Parts List. These are all carefully soldered into place next, making sure they are flush against the board. It is necessary to remove two locating "pips" on the underside of the specified switch – snip them off with sidecutters. The switches can be soldered in either way round.

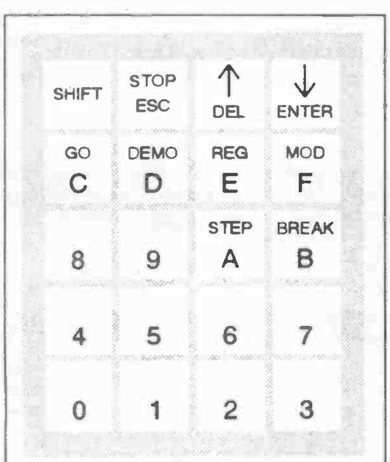
The keys have a push button cap fitted (reset is red) and it's possible to label each keypad neatly as follows: photocopy Fig. 2 then preferably cover with clear adhesive film of the type used for protecting book covers. This will give each key a glossy resilient finish.

On the rear of the photocopy, lay down some double-sided clear tape behind each label, then accurately slice out the labels with a scalpel. Remove the release-paper from the adhesive tape then stick each label down onto the appropriate keycap.

L.C.D. DISPLAY

Several types of 16 character, two line l.c.d. were tried and all worked satisfactorily. We suggest a Hitachi reflective type in the Parts List. Providing they are pin-compatible (and most types seem to be), there should be no problem with the electronic connections for equivalent types. However it is imperative that the l.c.d. has *mounting holes* which match those on the *Micro Lab* p.c.b. Definitely have plenty of "dry runs" with the l.c.d. display before finally committing to solder.

A 14-way s.i.l. pin header is soldered to the *Micro Lab*, to link the l.c.d. board to the main p.c.b., see Fig. 3. These pins stand proud from the *Micro Lab* board and must align with the solder pad holes of the chosen l.c.d. (as a last resort, use 14 short interconnecting wire links instead.) Use four 6mm stand-off spacers and bolt the l.c.d to the main board with M2 (2mm dia.) hardware, *ensuring that the s.i.l. pins pass through the 14 holes of the l.c.d. display.*



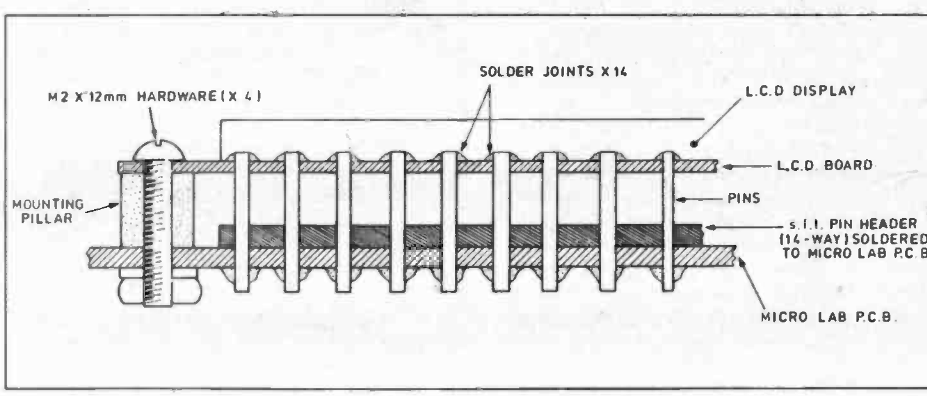


Fig. 3. Method of mounting l.c.d. display onto the Micro Lab *p.c.b.*

Fig. 2 (left). Keypad legends.

Mount the l.c.d. gently and evenly onto the *Micro Lab*, taking care that it is stood off from the *Micro Lab* board and that the 14 connections are indeed made properly. The pins **must** pass right through the l.c.d. board so that they can then be soldered to the l.c.d. printed circuit board on the uppermost side. Only solder this when you are sure that everything aligns properly.

A 10k 0·25W preset potentiometer with thumbwheel (VR1) is soldered nearby and this enables the *viewing angle* of the display to be adjusted. The sensitivity of this control depends very much on the individual l.c.d. chosen. It can be set to completely blank out the display in some cases – remember this when testing and setting up.

Next, insert the battery backup in the position marked on the board. It can only fit one way round. Follow on with the 34-way IDC (Insulation Displacement Connector) pin header which permits connection to the *Mini Lab*. The cut-out notch faces towards the l.c.d., and we specified the type of connector with "ejector lugs" so that the ribbon cable can be unhooked very easily when needed.

Add the 4-way screw terminal block CON5, which should conclude the soldering side of the construction. Now add five stand-off pillars to act as "feet" for the board. Finally, it is now safe to insert all the Integrated circuits into their respective sockets.

It goes without saying that the i.c.s are static-sensitive, therefore discharge any static which might have accumulated on your body by gripping an earthed object (e.g. a metal water pipe) before handling the chips. Ideally, use an anti-static wriststrap though this probably isn't compulsory.

All chips must be properly polarised. They tend to have either or both the familiar "horseshoe" shaped notch identifying one end, or pin-1 may be marked with a round dimple. There are eighteen chips to insert. The large 40-pin devices **must** be evenly and swiftly located into the holders, making quite certain that every pin is properly located into the socket. You may need to press one row of pins inwards a little beforehand, because they tend to be splayed out and don't always fit the socket to start with.

EPROM

The finishing touch is that part which gives your *EPE Micro Lab* its "intelligence" – the special "monitor" EPROM chip (IC2) which was custom-programmed for this design. Don't forget to add two s.i.l. jumpers to select "LEDS" and "+5V" on the *Micro Lab* p.c.b. which should complete the assembly of the *Micro Lab*. Next, the connection to the *Mini Lab*.

A short 34-way ribbon cable interconnects the *Mini* and *Micro Lab* boards, see Fig. 4. Make up the interconnecting ribbon cable using a length (e.g. 150mm to 300mm) of 34-way IDC ribbon cable. No soldering is needed with these cable connectors. Simply feed the ribbon cable through the header on top of each cable "socket" (SK1, SK2) then apply even pressure (e.g.. in a vice, or use pliers) to close the assembly tight. This forces the ribbon onto the connector's pins, piercing the insulation to make all 34 connections simultaneously. Double the ribbon back over the connector, and push on the cable strain relief supplied.

Referring to Fig. 5, the *Mini Lab* requires a matching 34-way IDC connector near the Logic Probe, along with s.i.l. sockets for Connectors 3, 4 and 5. The polarising notch

MICRO LAB COMPONENTS

Price £160 *Approx*

This list contains everything needed to construct the entire *Micro Lab*, with the exception of one small area called the "Printer Port". This will be described and listed in a future part. To maintain continuity with the numbering sequence, the small handful of parts needed for the printer port are shown as "**not used**".

Resistors

R1, R2	3k3 (2 off)
R3	1k5
R4	2k7
R5	15k
R6	d.i.l. resistor array 8 x 2k2
R7	15k
R8	d.i.l. resistor array 8 x 2k2
R9	3k3
R10	not used
R11	1k2
R12	390 ohms
R13	3k9
R14	82k
R16	10k
R17	390 ohms
R18	100k
R19	10k
R15, R20	wire link
R21	100 ohms
R22	4k7

All 0·25W 5% carbon film

Potentiometer

VR1	10k 0·25W horizontal preset and thumbwheel

Capacitors

C1 to C19	100n polyester 5mm pitch (19 off)
C20	100p polycarbonate/ ceramic 5mm pitch
C21	100µ tantalum 6·3V
C22	47µ tantalum 10V
C23	1µ tantalum 35V
C24	100p polycarbonate/ ceramic 5mm pitch
C25, C26	10µ tantalum 16V (2 off)
C27	100n polyester 5mm pitch
C28, C29	10µ tantalum 16V (2 off)
C30, C31	100n polyester 5mm pitch p.c.b. mounting (2 off)

See SHOP TALK Page

Semiconductors

D1	1N4148 silicon diode
D2 to D9	3mm red low current l.e.d. HLMP1700 (8 off)
D10	BAT46 Schottky barrier diode
DISP1	0·56in. common anode low current display
IC1	UM6502 CPU, 1MHz
IC2	27C256 programmed EPROM **(supplied with Micro Lab p.c.b.)**
IC3	256K low power SRAM, 120nS or less e.g. NEC 43256C-85L or HYUNDAI HY62256ALP-12
IC4	D8279 keyboard interface i.c.
IC5	7660 or 7661 CMOS Voltage converter
IC6	22CV10AP programmed PAL **(supplied with Micro Lab p.c.b.)**
IC7	74HCT04 hex inverter
IC8	74HCT73 dual JK flip-flop
IC9	74HCT20 dual 4-input NAND
IC10	74HCT373 Octal D-type latch
IC11	74HCT244 tristate buffer
IC12	R65C22P2 CMOS Versatile Interface Adaptor
IC13	not used
IC14	74HCT14 hex Schmitt inverter
IC15	74HCT00 quad NAND
IC16	ZN448E A/D converter
IC17	TL072P dual op-amp
IC18	ZN428E-8 D/A converter
T1	not used

N.B. 74LS can be used in place of 74HCT.

Mini Lab
34-way straight pin header with latches, as CON 1
s.i.l. turned pin socket strips 10-way (2 off), 8-way (1 off)

Miscellaneous

CON1	34-pin straight p.c.b. header, with latches
CON2	not used
CON3	14-way p.c.b. pin header (cut from 32-way strip)
CON4	not used
CON5	4-way p.c.b. screw terminal block
SK1, SK2	34-way IDC cable sockets (2 off)
LK1, LK2	3-way p.c.b. pin header (2 off) (2 strips of 3 pins)
LINKS	Shorting jumper links for LK1, LK2 (2 off)
XTAL1	2.000 MHz HC49 crystal
DISPLAY	16 character, 2 line l.c.d. display Hitachi LM016L or Toshiba TLCM1621
S1 to S21	S.P.N.O. p.c.b. mounted push switch (21 off)
B1	3V6 p.c.b. mounted nickel-cadmium battery
SW2*	8-way d.i.l. switch

Micro Lab p.c.b. and *Micro Lab User's Manual* (available from the EPE PCB Service, Order Code *MICRO*) turned-pin d.i.l. i.c. sockets; 8-way (2 off), 14-way (5 off), 16-way (1 off), 18-way (1 off), 20-way (3 off), 24-way **narrow type** (1 off – see text), 28-way (2 off), 40-way (3 off) = 18 total; push-on caps for S1 to S21 (20 off cream, 1 off red); 34-way ribbon cable, 150 to 300mm; l.c.d. mounting hardware, M2; p.c.b. mounting pillars, 5 off.
*N.B. There is no SW1

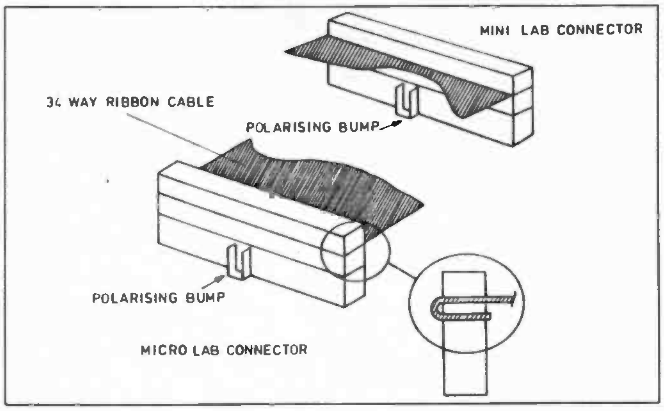


Fig. 4. Ribbon cable IDC assembly. It is essential that the polarising "bumps" are correctly orientated and the cable is not twisted.

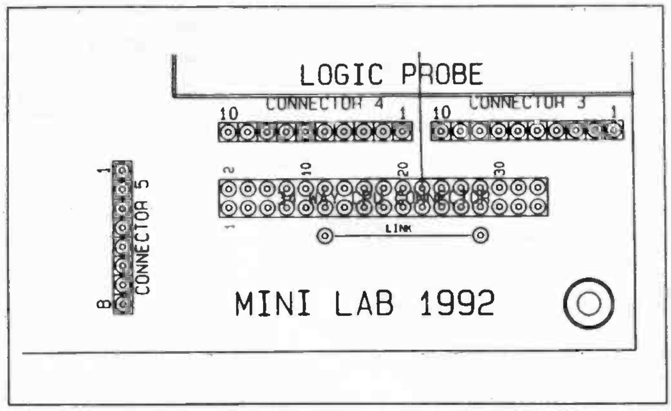


Fig. 5. Layout of connector on the Mini Lab board.

in the 34-way connector should face **away from** the Logic Probe. This should finally complete the assembly of the entire system.

POWERING UP

Obviously **you must thoroughly check every aspect of your assembly before powering up**. Look for dry or incomplete solder joints, excessive solder bridging adjacent solder pads (especially at the i.c.s), missing or reversed components, misaligned pins. Inspect each chip very closely to ensure that they are correctly polarised and that each and every pin is fully home in its respective socket. By now, your experience with the *Mini Lab* should be valuable in spotting any assembly problems.

Fit the ribbon connector cable between the *Mini* and *Micro Lab*. Set the "DISPLAY ADJUST" rotary control to fully anticlockwise then switch on the 5V rail. The display viewing angle might need adjusting, but you should see a fast initialisation routine on the l.c.d. (our notes are given adjacent):

Bios loaded [Basic Input/Output Operating System loaded 1]

Then you will quickly see:

Bios Loaded
O/S Loaded [Micro Lab Operating System Loaded]

The l.c.d. display will scroll up one line and show the welcome message:

O/S Loaded
Micro Lab V1.00 [Micro Lab Software Version Number 1]

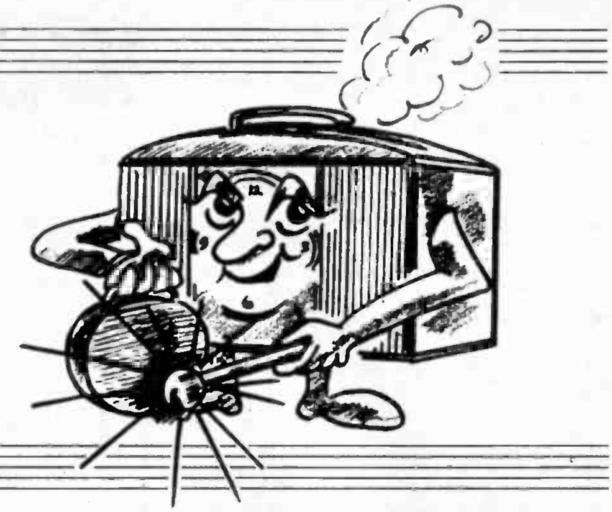
Finally, it will scroll once more to show its "ready" state along with a cursor:

Micro Lab V1.00
>_ [Cursor/ ready]

If you are with us thus far, very well done indeed! The usual hardware fault-finding techniques should be followed if you do not observe the start-up routine. In particular, adjust VR1 as needed and double-check the l.c.d. pin connections as well as the ribbon cable continuity, but there is every reason to expect a first-time success if you are an experienced constructor and have soldered the p.c.b. carefully.

There is no reason why you cannot use the keypad to experiment with the *Micro Lab* as no harm should befall it. Press RESET and the start-up routine should run again.

In Teach-In Part Ten, the *Micro Lab* is pressed into service when we investigate simple programming techniques and look at more of the theory behind microprocessors.



ELECTRONIC GONG

TERRY PINNELL

A versatile, pleasant sounding, output device with a wide range of applications.

ALTHOUGH this is an article about a versatile circuit, it was originally prompted by one very specific need.

I woke up one morning and decided to build an electronic gong. Or rather, more accurately, I was woken for the umpteenth time by the loud rasping of our bedside tea-making machine, announcing that it had finished its gurgling and spluttering phase and now required human intervention. I would hate to be without my morning resuscitator, but I do think it deserved a more civilized sound device than an electro-mechanical buzzer.

CHOICE SOUND

So, over the "Earl Grey", I resolved to replace it promptly with a less crude alternative. The possibilities were numerous, as any one of a variety of warblers, beepers or whistlers in my circuits reference binder would have served.

The choice of a gong sound was quickly reached. Whether emulating a bass drum, the bell of Big Ben or a cool xylophone, I thought it would make an appropriate rouser. It would obviously be intermittent and could therefore be switched off after the first percussion, without disturbing the local wildlife or neighbours. But above all I liked the potential versatility; I could see a gong circuit being used for sound output in a variety of other circuits, as indeed has since proved to be the case.

CIRCUIT OPERATION

The general circuit arrangement is shown in the block diagram of Fig.1. and the detailed circuit in Fig.2. Mains power is transformed to a non-critical d.c. voltage using a conventional arrangement of bridge rectifier and smoothing capacitor.

The heart of the circuit is an active twin-T filter using a 741 op-amp. The twin-T is normally used as the basis for a notch filter (or sometimes as a sine wave generator) but here it is set up to be on the threshold of oscillation, or "ringing". Fig.3. indicates how the twin-T gets its name.

The two separate T elements are just low-pass and high-pass filters. Combining them (the right way!) therefore produces a bandpass filter. Fig.3. also shows the relationship between the components values. The frequency can be calculated by:

$$F = 1/2\pi RC$$

Where F is the frequency in Hz, R is

Table 1.

R (k ohms)	*C (nF)*	*F (Hz)*
47	1·5	2260
56	1·5	1890
100	1·5	1060
180	1·5	590
220	**1·5**	**480**
390	1·5	270
470	1·5	230
560	1·5	190
680	1·5	160
1000	1·5	110
1200	1·5	90

The bold values are the ones used in the prototype.

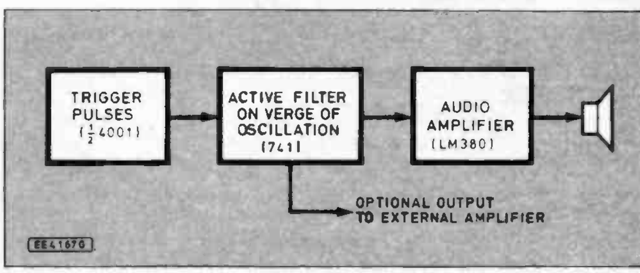
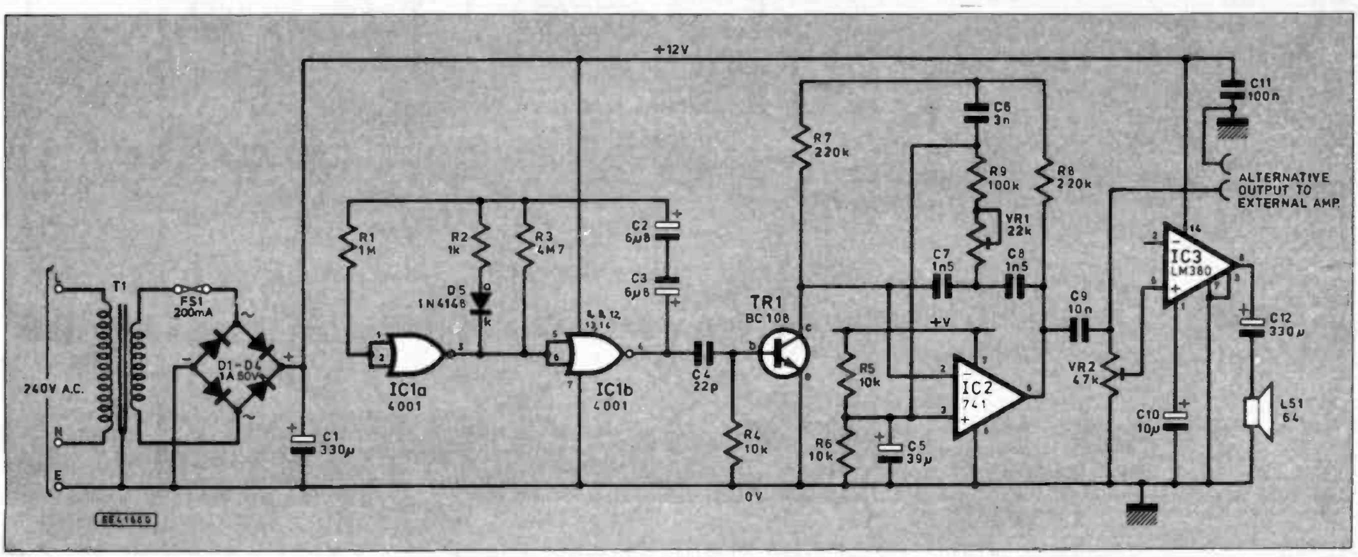


Fig. 1. Block diagram for the Electronic Gong.

Fig. 2. Full circuit diagram for the Electronic Gong. The speaker LS1 rating can range from 8 ohm upwards.



the resistance in Ohms, and *C* is the capacitance in Farads.

Using more convenient units and with *C* fixed at 1n5 (1500pF) the formula gives the results shown in Table 1 for various values of resistance.

If you want to try a bass drum sound, then use 1M resistors for R7 and R8 instead of 220k. You would then also have to alter the values of R9 and VR1 so that their combined resistance could be adjusted to about 500k, which would probably be best achieved with a fixed resistor, R9 of 470k and a preset VR1 of 47k. Naturally, if you are using a miniature speaker as specified in the basic circuit, then don't expect it to do justice to your bass drum anyway.

Note that there is no need for a dual polarity supply with this 741 circuit, the "common" line being generated artificially by voltage divider R5 and R6, smoothed by C5. Fig. 4 shows the output waveform generated.

The trigger pulses could be generated in several ways, such as with a 555 or discrete transistors. The circuit used is an asymmetrical version of astable multivibrator,

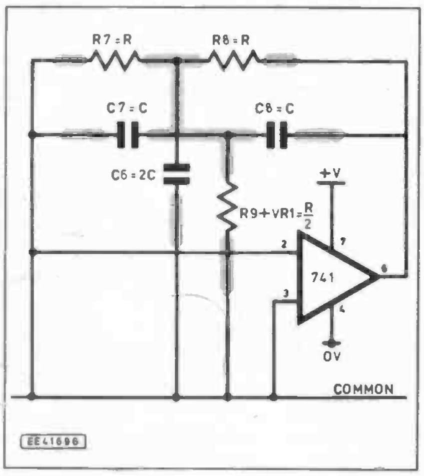


Fig. 3. Elements of the active twin-T filter in the gong.

improved by adding R1 to minimise voltage dependency.

When experimenting initially with a symmetrical version there was an audible "click" on the negative-going edge of the rectangular wave output from pin 4. Although hardly a problem in a tea-maker, it could be unacceptable in other applications. Adding R2 and D5 provides a fast alternative discharge path, so that the output becomes a series of very sharp pulses, about 12 seconds apart.

One requirement of simple CMOS astables is that the timing capacitor must be non-polarised. For short periods this is never a problem, because the values of *C* are always low, e.g. below 1µ. The timing period T in seconds is roughly equal to 0·7*RC*, where *R* is in megohms and *C* is in microfarads. This means *C* is about 1.4T/*R*. Therefore, for periods of above say five seconds and keeping *R* to below say 5M, the timing capacitor will need to be greater than 1µ4, so would normally have to be electrolytic.

This problem is easily resolved by using a *pair* of equal value electrolytics, in series, back-to-back, as shown in the circuit diagram. The resultant capacitance is half the value of each of the individual ones and the voltage rating is doubled. (Incidentally, they don't have to be equal in value, but this makes the calculation simple. For *any* two values C1 and C2 the resultant value *C* is calculated, like resistors in parallel, from $1/C = 1/C1 + 1/C2$.)

The output from pin 4 of the 4001 is coupled by a diminutive capacitor to an *npn* transistor, of virtually any simple type, which therefore conducts briefly, taking pin 2 of the 741 close to 0V at a low impedance, which is all that is needed to strike the gong.

The amplifier section is a straightforward fixed gain LM380 circuit, with input via preset VR2 to allow the volume to be adjusted. Any speaker of greater than 8 ohms impedance is suitable and in practice it is mainly a question of what maximum volume you need – the smaller the impedance, the louder the result at any given VR2 setting.

COMPONENTS

Approx cost guidance only **£15**

See SHOP TALK Page

Resistors

R1	1M
R2	1k
R3	4M7
R4 to R6	10k (3 off)
R7, R8	220k (2 off)
R9	100k

All ¼ watt 5% unless otherwise stated

Potentiometers

VR1	22k horiz. preset
VR2	47k horiz. preset

Capacitors

C1, C12	330µ radial elect. 16V, 0·2in. pitch (2 off)
C2, C3	6µ8 radial elect. 10V, 0·15in. or 0·2in. pitch (2 off)
C4	22p ceramic, 0·2in. pitch
C5	39µ radial elect., 10V, 0·2in. pitch
C6	3n polystyrene, 0·7in. pitch
C7, C8	1n5 polystyrene, 0·7in. pitch
C9	10n ceramic, 0·1in. pitch
C10	10µ radial elect., 16V 0·2in. pitch
C11	100n ceramic, 0·2in. pitch

Semiconductors

D1 to D4	1A 50V bridge rectifier
D5	1N4148 silicon signal diode
TR1	BC108 *npn* silicon transistor
IC1	4001 CMOS quad 2 input NOR gate
IC2	741 op.amp
IC3	LM380 14 pin audio amplifier

Miscellaneous

FS1	200mA 240V p.c.b. mounting fuse
T1	Min. mains transformer, 12V 100mA (mounted by nuts/bolts to p.c.b., 1·8in.)
LS1	Min. 64 ohm loudspeaker

I.C. sockets (2 x 14 pin, 1 x 8 pin); 2-core mains cable (and associated clamp, grommet etc, if needed); nuts and bolts to secure transformer; p.c.b. stand-offs; connecting wire; solder.

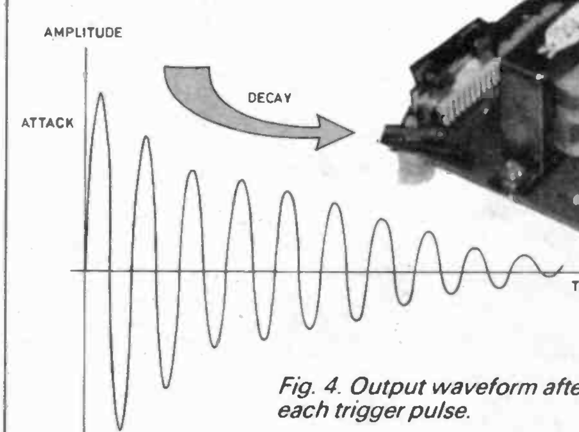
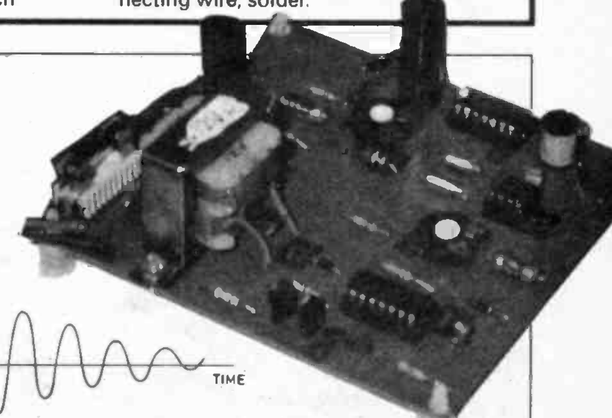
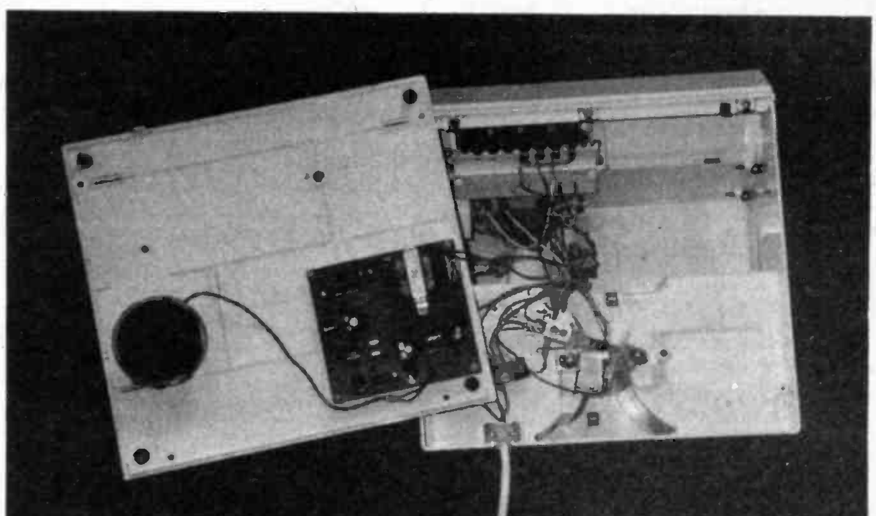


Fig. 4. Output waveform after each trigger pulse.





The completed circuit board and miniature loudspeaker mounted on the base panel of the "tea-maker".

CONSTRUCTION

A suggested p.c.b. layout is illustrated full size in Fig. 5. Components are not critical in value, providing the twin-T resistors R7 and R8 and capacitors C7 and C8 are within at least five per cent of each other. The two back-to-back capacitors C2 and C3 used have pin spacings of 0·15 inch, alternative pads have been included on the p.c.b. with the more common 0·2 inch pitch. The miniature transformer was mounted on the board for convenience, using a couple of nuts and bolts. Its frame is earthed via the p.c.b.

The mounting of the speaker will depend on the intended purpose of your gong circuit. I took an approach I sometimes use when the speaker does not have to face outward. I just pushed its round rear end into a flush-fitting plastic top, salvaged from some container or other; a roll of tape can be used for minor adjustments.

This was then fastened inside the base of the tea-maker using a self-tapping screw from outside into the middle of the plastic top; choosing the self-tapper's length so that when tight the point of the screw cleared the end of the speaker. The p.c.b. itself, fitted with pillars in each corner, was also secured to the base of the tea-maker.

SETTING UP

Before applying power, it is sensible to make the usual basic checks, including measuring the resistance across the mains supply inputs to ensure they have not somehow been shorted out or wired to the transformer's secondary. With mains-powered projects, it is often a good idea to first test the circuit using a bench d.c. power supply.

This circuit is in no way fussy about the power supply voltage, incidentally, tolerating anything from about 9V (below which the LM380 does not perform reliably) to 15V (above which CMOS circuits like the 4001 tend to get zapped.)

With power applied it is then just a matter of setting the twin-T so that it is just about to oscillate. In practice, VR1 is carefully adjusted so that the circuit oscillates steadily, then increased by turning clockwise a fraction so that it fades to silence. As shown in Fig.4., its "attack" when triggered will be immediate but its decay time will depend on how critically VR1 is set.

If VR1 is turned to maximum resistance, there will be fast decay, or perhaps no oscillation, just a "clunk". With VR1 at the other end of its range, oscillation should be constant, i.e., no decay. The preferred setting will also be influenced by the triggering period.

With the *RC* component values used the delay between pulses is about 12 seconds. With VR1 set very critically, for maximum decay and hence a satisfying reverberation, the sound may not have completely disappeared when the next trigger pulse arrives. Finally, VR2 should be adjusted to give the required volume level.

A GONG FOR...

The same circuit has subsequently been used in a car alarm unit providing a repetitive warning alert during the exit and re-entry periods and also being triggered to give between one and four chimes on detecting various conditions such as low fuel, low washer fluid and icy temperatures.

Lots of other possibilities come to mind, such as using the gong in a prowler alarm, a proximity detector or (with some challenging logic circuitry) as a clock chimer. □

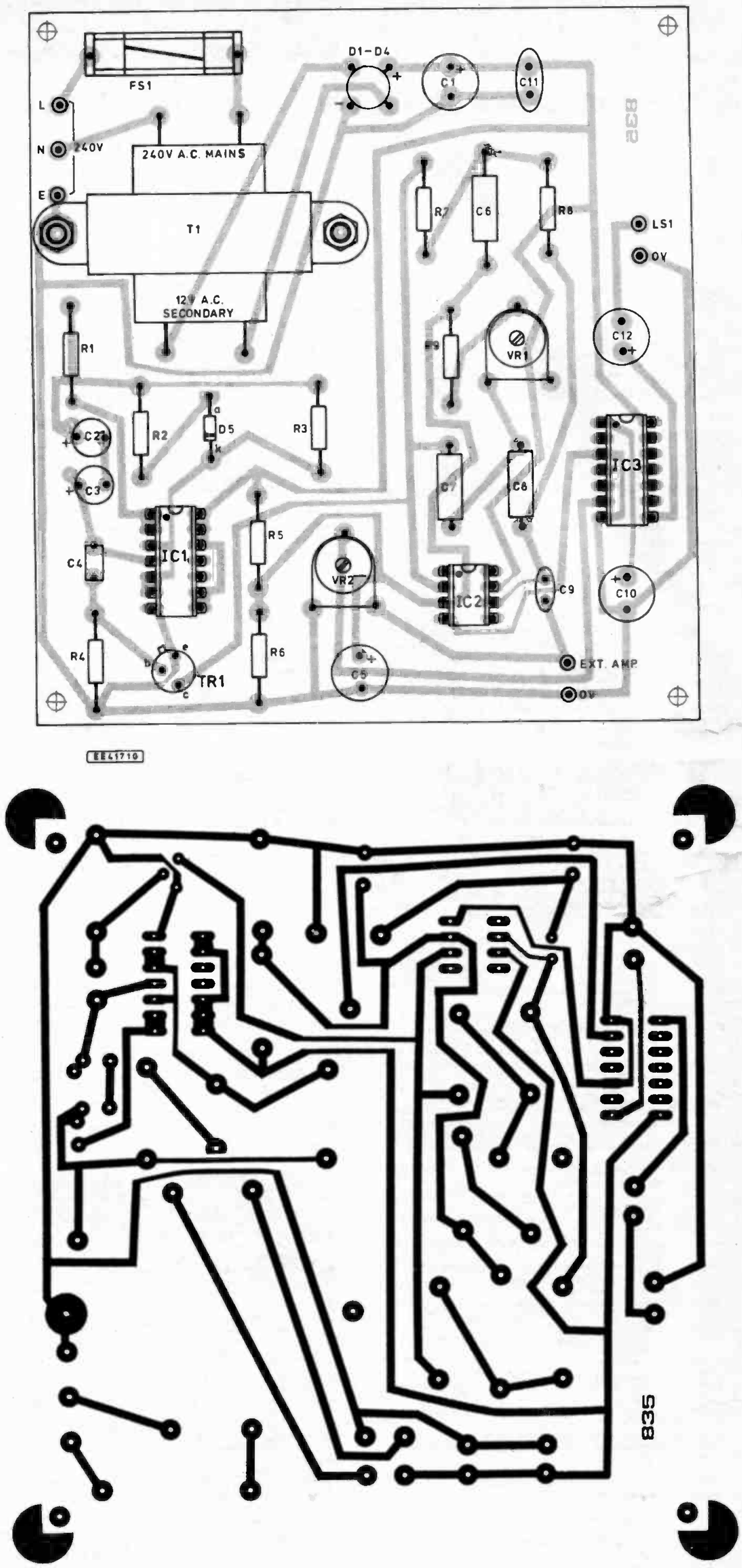
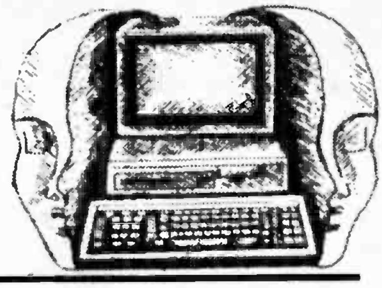


Fig. 5. Printed circuit board component layout and full size underside copper foil master pattern. This board is available from the EPE PCB Service.

INTERFACE



Robert Penfold

IN last month's *Interface* article the subject of single bit speech synthesised was introduced. An interface circuit for recording speech samples into a PC was included, and although this works well enough, it gives something less than the ultimate in single bit speech quality. Further experiments with single bit speech synthesis resulted in the improved recording interface circuit of Fig.1.

Highpass Filtering

As explained last month, in order to obtain intelligible speech from a simple single bit system it is essential that the speech signal is subjected to highpass filtering prior to clipping. Without this filtering the low frequencies in the voice signal tend to produce a final output that is essentially just "clicking" and "buzzing" sounds.

Even some very simple highpass filtering produces a dramatic improvement in the output quality. In my original recording interface there was no highpass filter as such, but the use of low value coupling capacitors produced sufficient low frequency attenuation to give reasonable results.

The main difference between the present design and its predecessor is that this one incorporates a proper highpass filter stage. This substantially increases the complexity of the circuit, although it is still reasonably simple and inexpensive to construct.

Even with the addition of proper filtering the output quality is far from hi-fi. The improved filtering seems to give a very worthwhile improvement in speech quality though, and probably delivers results that are as good as a single bit system of this type can provide.

The filter has IC1 as a buffer stage at the input, and this ensures that the CR network is fed from a suitably low source impedance. The filter itself is a conventional four section (24dB per octave) active type based on IC2.

The generally accepted wisdom is that frequencies below about 250Hz to 300Hz are not important to the intelligibility of speech. In fact these frequencies can be a hinderance. This is certainly the case in the present context, and a filter cut-off frequency of no less than about 250Hz seems to be needed in order to produce good results. The ideal cut-off frequency probably varies somewhat from one voice to another, but in general results seem to be best using a cut-off frequency of around 400Hz to 500Hz.

Components

Using the specified values for capacitors C5 to C8 gives a cut-off frequency of just under 500Hz. The filter frequency is easily changed by using a different value for these capacitors, and the cut-off frequency is inversely proportional to the value used (i.e. a doubling of value gives a halving of the cut-off frequency).

It is important that *all four* capacitors should have the same value. Otherwise it is likely that a pronounced peak and other irregularities will occur in the filter's passband. The filter could even break into oscillation. C5 to C8 and R4 to R8 should have a tolerance of 5 per cent or better.

The main output of the unit couples to one of the PC's serial ports, but some of the output is fed to JK2 via attenuation resistor R11. A crystal earphone is connected to JK2, and this enables the output to be monitored so that VR1 and VR2 can be set for optimum results. VR1 is a volume control style gain control which is set just high enough to give a strong output signal.

Potentiometer VR2 controls the reference level fed to the comparator at the output of the unit. This must be set close to the point at which the output of the comparator switches state. A noise will be clearly heard from the earphone as VR2 is adjusted through the setting at which the output switches over from one state to the other. A little "fine tuning" of VR2 will then optimise results.

In Isolation

The speech output produced using such a simple method of digitising is in many ways quite rough, and the distortion level is certainly very high. On the other hand, there is no problem with intelligibility, and the played-back voice is usually quite recognisable. The same is not always true of more sophisticated methods of digital speech synthesis.

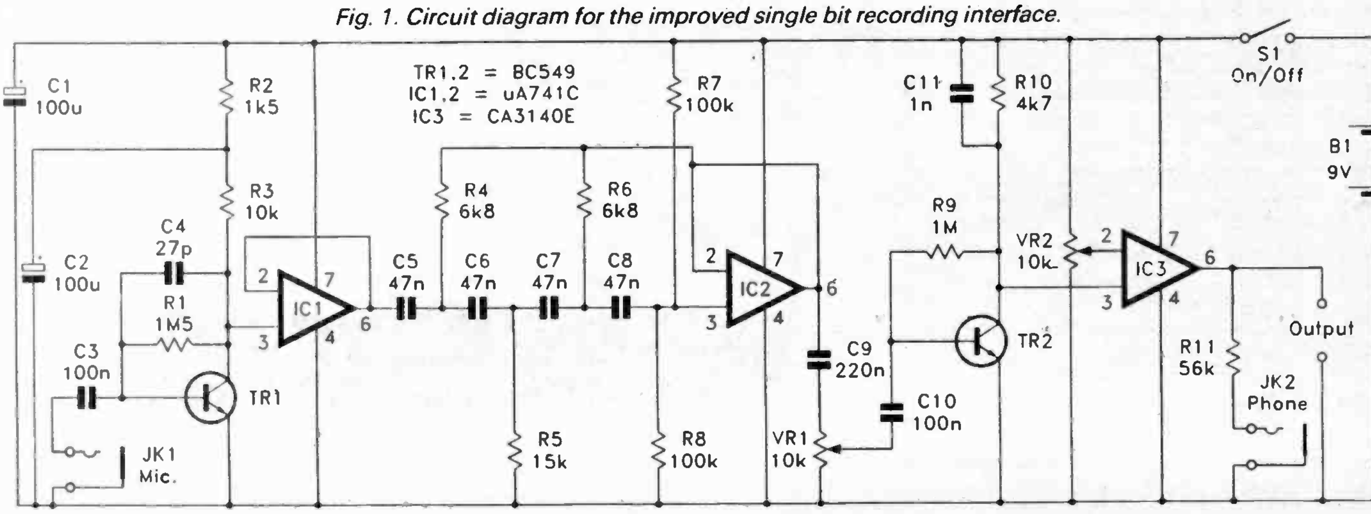
I encountered only one major problem with this method of digitising, and it is a problem that can strike whenever a sensitive audio circuit is connected to digital equipment. Digital circuits are first rate generators of electrical noise, and this noise always seems to find its way into the audio signal path. Using a battery supply for the audio circuit rather than powering the interface from the computer helps to minimise the problem, but does not eliminate it.

If the noise pickup is very severe, the most likely cause is inductive pickup via the coil in the dynamic microphone. Keeping the microphone well away from the computer and the monitor should reduce the noise breakthrough. The level of pickup depends on the orientation of the microphone, and it is usually possible to find an orientation that will null the background hubbub.

Opto-Isolator

Even with no noise pickup via the microphone, there is likely to be a certain amount of noise coupled via the earth line.

Fig. 1. Circuit diagram for the improved single bit recording interface.



This can be eliminated using an opto-isolator circuit. This couples the digital signal from the interface to the computer, but without using any direct electrical connection between the two. This removes the coupling via the earth line, and any noise which it would otherwise permit to flow from the computer to the audio circuits.

Inexpensive opto-isolators are quite slow by electronic standards, and are slightly too slow to accurately couple the digitised audio signal through to the computer. However, an inexpensive opto-isolator plus a single transistor amplifier provide a switching speed that is substantially more than adequate for the current application.

The improvement in switching speed that can be obtained using this method is surprisingly large. The switching speed seems to be improved by a factor of around 100.

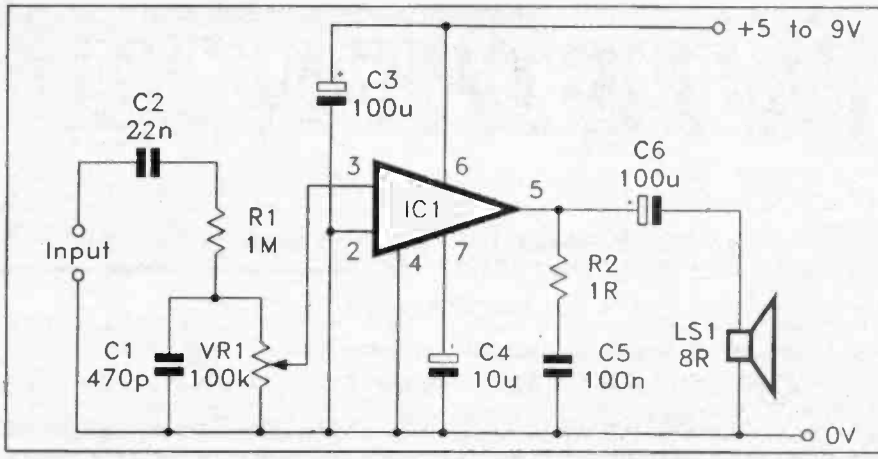


Fig. 2. Circuit diagram for a simple audio amplifier, based on the LM386N power amp. i.c., for use when playing back recorded speech samples.

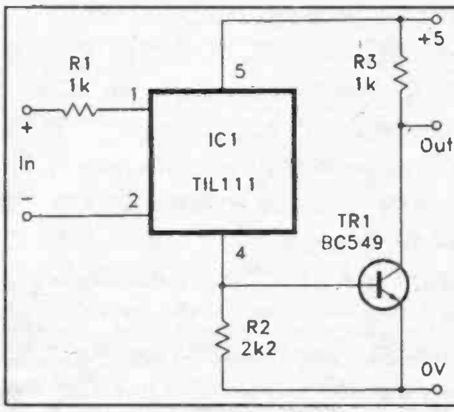


Fig. 2. An opto-isolator circuit to avoid noise being coupled through the Earth rail.

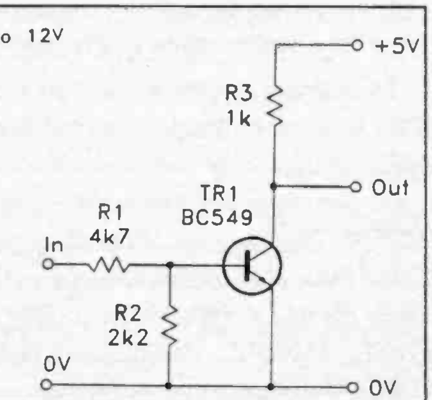


Fig. 3. A level shifter circuit to enable the speech recording interface to drive standard 5V logic inputs.

An opto-isolator circuit which utilizes a discrete switching transistor is shown in Fig. 2. R1 is the current limiting resistor for the infra-red l.e.d. on the input side of the opto-isolator (IC1). An advantage of using the opto-isolator in conjunction with an amplifier stage is that it enables satisfactory results to be obtained using a relatively low drive current. In this case the input current is only about five milliamps, but this is still substantially more than the minimum requirement.

On the output side of IC1 only the collector and emitter terminals of the phototransistor are utilized. Normally the leakage current through the phototransistor is inadequate to bias TR1 into conduction. However, when the l.e.d. is activated the leakage level becomes much higher, and TR1 becomes fully switched on.

Of course, the opto-isolator circuit must be powered from a different supply to that used for the speech interface. This could be a second 9 volt battery, but there should be no difficulty in using the +5V or +12V supply line of the computer. Although the circuit diagram shows IC1 as a TIL111, any "bog standard" opto-isolator (4N27, etc.) should work properly in this circuit.

Other Computers

The recording interface can be used with any computer that has a spare digital input line. However, the 9 volt output level of the interface must be reduced to standard 5 volt logic levels, or there is a risk of damaging the computer's input port. The best way of achieving this is to use the opto-isolator circuit with a 5V supply.

Alternatively, the simple level shifter circuit of Fig.3 can be used, but this obviously does not prevent stray coupling of noise through the "earth" or common rail.

It might be possible to play back recorded sequences via the computer's sound generator, but in most cases it will be necessary to use a digital output port driving a small audio amplifier. Fig.4 shows a suitable audio amplifier circuit which is based on the LM386N power amplifier chip.

Software

The software side of things is likely to be a little more awkward. A sample rate of about 17kHz is required, which is far too fast for most BASICs to have any chance of handling the task properly. Not all high level languages are well equipped for the bit level manipulations required in this application, and a machine code routine would seem to be the most appropriate solution.

The recording and playback process is a fairly simple one, which does not require any advanced programming techniques. Obtaining a suitable recording and playback rate will probably require a certain amount of experimentation though.

In my experience of high speed sampling systems the main problem is likely to be the computer's heavy use of interrupts. This tends to produce erratic timing during both "record" and "playback", and in most cases it is essential to disable all or some of the interrupts. In this case the sampling rate is not particularly high, but quite small irregularities in the timing seem to have dire consequences for the audio output quality.

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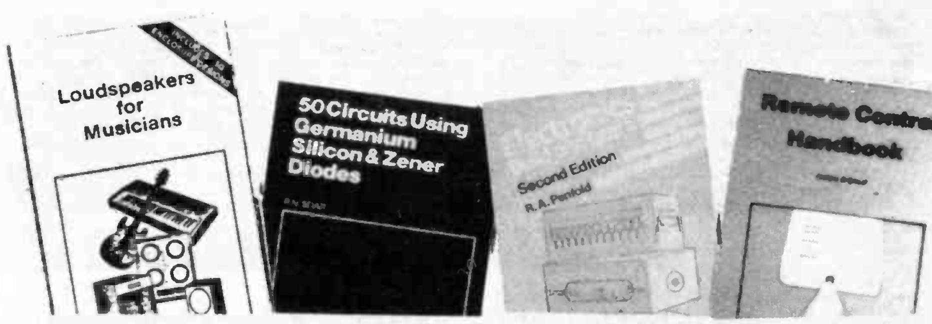

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VT203 57 minutes. Part three; Semiconductors. Gives you an exciting look into the world of semiconductors. With basic semiconductor theory. Plus 15 different semiconductor devices explained. **Order Code VT203**

VT204 56 minutes. Part four; Power Supplies. Guides you step by step through different sections of a power supply. **Order Code VT204**

VT205 57 minutes. Part five; Amplifiers. Shows you how amplifiers work as you have never seen them before. Class A, class B, class C, op.amps. etc. **Order Code VT205**

VT206 56 minutes. Part six; Oscillators. Oscillators are found in both linear and digital circuits. Gives a good basic background in oscillator circuits. **Order Code VT206**

By the time you have completed VT206 you have completed the basic electronics course and should have a good understanding of the operation of basic circuit elements.

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VT101 54 minutes: A step-by-step easy to follow procedure for professionally cleaning the tape path and replacing many of the belts in most VHS VCR's. The viewer will also become familiar with the various parts found in the tape path. **Order Code VT101**

VT102 84 minutes: Introduction to VCR Repair. Warning, not for the beginner. Through the use of block diagrams this video will take you through the various circuits found in the VHS system. You will follow the signal from the input to the audio/video heads then from the heads back to the output. **Order Code VT102**

Now for the digital series of six videos. This series is designed to provide a good grounding in computer technology.

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VT302 55 minutes. Digital Two will further enhance your knowledge of digital basics. You will learn about Octal and Hexadecimal notation groups, flip-flops, counters, etc. **Order Code VT302**

VT303 56 minutes. Digital Three is your next step in obtaining a solid understanding of the basic circuits found in todays digital design. Gets into multiplexers, registers, display devices, etc. **Order Code VT303**

VT304 57 minutes. Digital Four shows you how the computer is able to communicate with the real world. You will learn about digital to analogue and analogue to digital converter circuits. **Order Code VT304**

VT305 56 minutes. Digital Five introduces you to the technology used in many of todays memory devices. You will learn all about ROM devices and then proceed into PROM, EPROM, EEPROM, SRAM, DRAM, and MBM devices. **Order Code VT305**

VT306 56 minutes. Digital Six gives you a thorough understanding in the basics of the central processing unit and the input/output circuits used to make the system work. **Order Code VT306**

By now you should have a good understanding of computer technology and what makes computers work. This series is also invaluable to the computer technician to understand the basics and thus aid troubleshooting.

Each video uses a mixture of animated current flow in circuits plus text, plus cartoon instruction etc., and a very full commentary to get the points across. The tapes are imported by us and originate from VCR Educational Products Co, an American supplier.

(All videos are to the UK PAL standard on VHS tapes)

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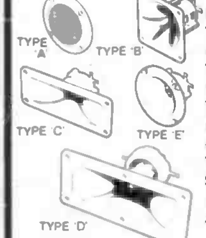

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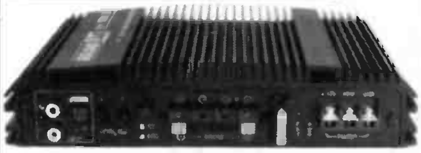

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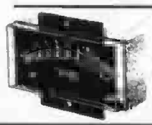

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