# PRACTICAL ELECTRONICS

JANUARY 1990 • £1.25

SCIENCE AND TECHNOLOGY

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Thwart The Hi-Jack With A Pluggable Triac Jack

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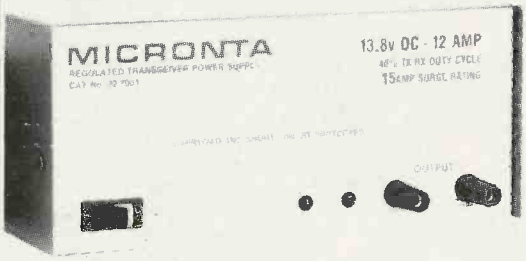
MICRONTA
REGULATED TRANSCEIVER POWER SUPPLY
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15AMP SURGE RATING
OUTPUT

# PRACTICAL ELECTRONICS

VOL 26 NO 1 JANUARY 1990

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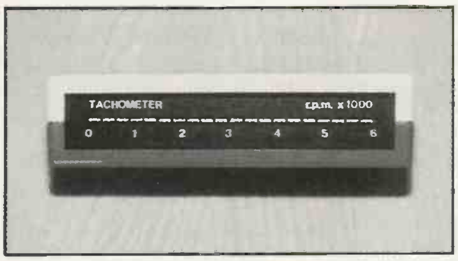

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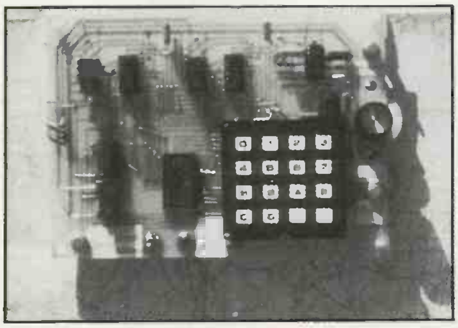

## NEXT MONTH

There's a brand new series on computers, detailing their essential characteristics, and what you should know to understand the technology. Still on computing, join us in the world of hi-tech communications by building our modem project. And we've lots of other great features in advanced preparation that we're sure you'll find fascinating,

★ SO DON'T MISS OUR FEBRUARY 1990 ISSUE

★ ON SALE FROM FRIDAY JANUARY 5TH

★ YOU CAN'T BEAT OUR VALUE

★ OR OUR CELEBRATED OFFERINGS!

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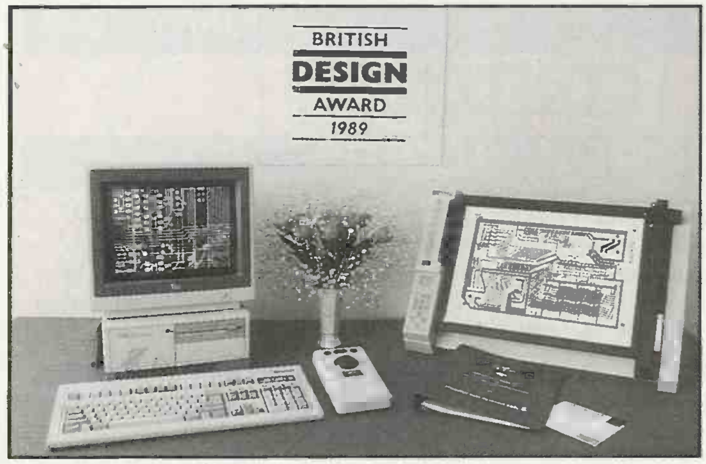
# NEWS



# REDUCING CAD PCBS

Number One Systems has announced a major change in pricing and sales policy on its best-selling EASY-PC printed circuit board layout and schematic draughting software package. True to its altruistic aims of "Making Electronics CAD affordable", the company has reduced the price to just £98.00 plus VAT.

Managing Director Adrian Espin commented, "Sales and resulting customer response have been outstanding to the extent that we have recovered our initial launch and development costs much sooner than anticipated. We have also decided to include both the HP-GL pen plotter and Gerber Photoplotter output drivers in with the basic price of EAST-PC."

This makes EASY-PC a package for professional quality pcb artwork creation and schematic diagram drawing that, according to Adrian Espin, "no electronics engineer can now afford to be without."

The package was singled out for praise by the 1989 British Design Awards judges for its simple and responsive user interface, and for its exceptional speeds of zoom, pan and redraw without the use of expensive co-processors.

**For more information contact:** Roger Wareham, Technical Director, Number One Systems Ltd, Harding Way, Somersham Road, St Ives, Huntingdon, Cambs PE17 4WR. Tel: 0480 61778.

# MAPLIN IR CONTROL

Image, status, convenience and safety are all factors contained in the latest Maplin Electronics "Sound Master" kit. The infra-red remote control switch has a range in excess of 10 metres, ideal for situations where it may be impractical or inconvenient to use direct manual switching. Such remote operational areas include garage doors, loft, patio or passageway lighting.

The controller will not only eliminate the need for unsightly or difficult-to-install wiring, but interference associated with radio control systems.

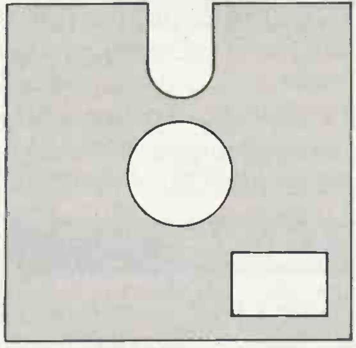
The project will provide remote switching of a single pole changeover relay with the provision of either selecting a latched output or momentary output. Leds on both the transmitter and receiver flash when they are operating. A purpose made case is provided for the transmitter although the receiver needs to be housed, preferably in a metal enclosure.

All parts for the transmitter and receiver, excluding a metal case for the receiver, are included in the kit.

The order code for the IR remote switch kit is LM69A, and it costs c £17.95, plus VAT.

**For further information contact** any of Maplin's nationwide shops.

# CATALOGUE



## Continuing our alphabetical browse through advertisers' literature

**Fluke**, who are part of the **Philips Group**, have sent a massive hardbound catalogue of nearly 600 pages. In it, you should find practically every item of **very high quality test and measurement gear** that you could ever want. The range includes oscilloscopes, multimeters, logic analyzers, signal sources, recorders, power supplies, video test equipment, counters and timers, etc. This really is a **catalogue for the very serious constructor** who is probably at the semi-professional standard. For information on how to obtain the catalogue, contact **Philips Scientific Test & Measurement**, Colonial Way, Watford, Herts, WD2 4TT. Tel : 0923 240511.

**Roadstar** are a Swiss company who specialise in **hifi systems and equipment for a wide variety of automobile purposes**. They have sent in a bundle of data sheets, specifications and promotional literature. It's highly apparent that anyone wanting to add sound to their wheels should **definitely give close attention to Roadstar's large range**. One item particularly caught my eye - **a high power autoreverse car cassette player** with lcd, lw/mw/fm/fm-stereo pll radio and tuner with 18 memories, separate bass and treble, and a line output. The **power is quoted at 64 watts** - nearly enough with which to operate a truly mobile disco! Ask your local car-audio stockist for more information on this range, or write to **Roadstar**, F.E.Fender Electronics SA, Via Passeggiata 1, CH-6828 Balerna, Switzerland.

**Sherwood Data Systems** have sent a selection of interesting data sheets which mainly relate to **single board computers**. These include the SDS Archer, based on the Z80A microprocessor family, the Bowman, based on the 68000, and the Lancer which is based on the 8088. **Various daughter boards and other accessories** are available as well. **Sherwood Data Systems**, Sherwood House, York Way, Cressex Industrial Estate, High Wycombe, HP12 3PY. Tel : 0494 464264.

**Softmachine's** price list recently received is marked as confidential **for the trade only**. It covers **computer casings**, power supplies, keyboards, **main computer boards**, add-on cards, monitors, computer tools and a selection of spares and cables. **Softmachine Distribution Ltd**, Units F18/F25, Harbet Road, Lea Valley, Edmonton, London N18 3LR. Tel : 01-807 2748.

**SCS Components** are electronic component distributors. Their 78-page A4 mail order catalogue has been recently released and features a **wide range of kits, components, connectors, etc**, for both the professional and the enthusiast. It will cost you a mere 50p and is a **worth while addition** to your catalogue library. **SCS Components**, 218 Portland Road, Hove, East Sussex, BN3 5QT.

**Specialist Semiconductors** have an interesting selection of **unusual kits available** in their price list. The first page includes **projects which relate to your health**, such as air ionisers, a brainwave monitor, and a biofeedback monitor. Other kits include mains purifiers, surveillance equipment, fitness monitor, tv booster, and a selection of **other fascinating looking subjects**. There are also books available on biofeedback techniques. Don't miss out on this source of interesting projects, ask for a copy of the list. **Specialist Semiconductors**, Founders House, Redbrook, Monmouth, Gwent.

# NEWS

## WAVE CRESTING

Designed for use on-board yachts and boats, the new Grundig Satellit 500 International radio has just about every feature you could wish for. Sailors and land-lubbers alike can enjoy the Satellit 500s to receive music, news, and programmes from around the world along with all shipping forecasts. Additional capabilities of the easy-to-use radios amply cater for both amateurs and professionals.

The radio has a memory which can store up to 42 stations freely programmed by the user. For simplified searching, all stations are easily identified by an alphanumeric readout shown on the large, easy-to-read, illuminated lcd display. This also acts as a multifunction information centre and indicates the frequency range, waveband, memory, position, field stregth, and shows if there is faulty operation.

Special features include a rechargeable battery with a built in recharger, automatic station search and scan functions, along with demodulators to improve the sound quality and aid reception of weak or unstable signals. The telescopic aerial rotates freely, but may also be 'locked' into a number of useful set positions. Reception capabilities include short wave, medium wave, long wave and fm stereo, and there is a reception range of 1.6 to 30MHz. Stereo sound is provided via headphones or an additional speaker.

The timer has a clock with two time zones and a time switch for turning on and then turning off two different radio stations. If the sleep timer is used, the radio will gently play while the listener falls asleep and will then turn itself off after a pre-set time of anything from 10-60 minutes.

There is a threaded socket for on-board mounting when used in a boat, and a practical cover to offer protection from the elements.

Measuring 30.4 cm x 17.8cm x 6.6cm the radio weighs approximately 1.8kg and is housed in a black/grey metallic cabinet.

Priced at £299.95 the Satellit 500 is available from selected Grundig Dealers nationally.

Your Ed hopes Santa might generously present him with one at Christmas!

**For more information contact:** Hammond and Deacon Ltd, 4 Earlham Street, London WC2H 9LA. Tel: 01-379 7945.

## EVENTS DIARY

If you are organising any event to do with electronics, big or small, drop us a line, we shall be glad to include it here.

**Please note** : Some events listed here may be trade or restricted category only. Also, we cannot guarantee information accuracy, so check details with the organisers before setting out.

**Dec 5**. Safe use of electricity at work. IEEE lecture. Chester. 01-836 3357.

**Mar 7-8.** Laboratory 90. G-Mex Centre, Manchester. 0799 26699.

**Mar 9-10**. London Amateur Radio Show. Picketts Lock Centre, Edmonton, North London. Advance ticket sales and trade enquiries to The Secretary. LARS, 126 Mount Pleasant Lane, Bricket Wood, Herts AL2 3XD. 0923 678770.

**Mar 28-29**. Laboratory, Science & Technology Show. Kelsey Kerridge Sports Hall, Cambridge. 0799 26699.

**Apr 9-11.** Cable and satellite exhibition and conference. Olympia, London. 01-486 1951.

**Apr 4-5**. Drives, Motors, Controls. New Century Hall, Manchester. 0799 26699.

**Apr 24-26**. British Electronics Week. Olympia, London. 0799 26699.

**Jun 26-28**. Infrared Technology. Wembley Conference Centre. 0799 26699.

**Sep 25-27**. British Laboratory Week. Olympia, London. 0799 26699.

## WAKE UP WITH MAPLIN

The new attractively designed Maplin alarm clock radio helps you go to sleep and awake in style. Whether your personal turn-on is for Radio 1, 2, 3 or 4, the independent stations or the local taxi cab radio control room, Maplin say that their alarm clock radio will meet your every sound requirement. Or you can choose to be awakened by a melliferous buzzer!

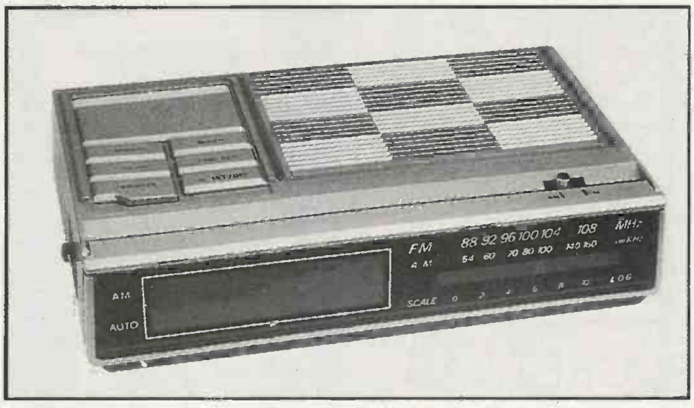
But there is no respite for the heavy sleeper. The radio or alarm signal will continue to sound for two hours. You can however grab that extra sleep period when the snooze facility is used. This will activate the radio or alarm signal every nine minutes.

Meanwhile, the power cut fail safe function features a basic PP3-type battery which serves to maintain the internal time keeping. However, if your local power supplies have not been re-established by the normal alarm sounding time, as is the case with all mains electrical-powered alarm clocks, natural waking procedures will be required, if the day's routines are to be met.

The battery, incidentally, will last for a period of up to 10 years, sufficient time to see out very many power-cuts.

Specs: AM Waveband, 525 to 1605kHz: VHF FM band, 88 to 108MHz.

Sleep time adjustable for a period from 1 min. to 2 hours.



Overall size: 182 x 114 x 48mm high.

Maplin's order code for the alarm clock radio is YT14Q, and the price is £8.95 including VAT.

**For further information,** please contact: Doug Simmons, Maplin Electronics, PO Box 3, Rayleigh, Essex SS6 8LR. Tel: 0702 554161.

# METICULOUS METRICATION

Higlighting details of several new meters for which we have been sent information. If you're looking for Christmas presents you might find one here!

## FLUKE 80s

Fluke 80 Series multimeters are now available ex-stock from Universal Instruments of Leicester who say that all three models offer more measurement capability than other dmm plus state of the art analogue and digital performance. They not only measure volts, ohms, amps, check continuity and perform diode tests, they also measure frequency, duty cycle and capacitance while allowing simultaneous measurement of minimum, maximum and true averages - which other handheld meters do not.

Liquid crystal displays give a 3.75 or 4.5 digit. 4000 or 20,000 count updated four times a second. The extra large display tells all with every measurement being fully annunciated. Fluke models 83 and 85 have a bargraph for analogue reading that updates 40 times per second to capture changing or unstable signals, and a x10 zoom mode for higher resolution. Analogue readings on the 87, a true rms meter, use a full-time high resolution pointer with a backlit display that comes on at the touch of a button and goes off automatically after 68 seconds.

The prices, excluding VAT are £153 for the 83, £179 for the 85 and £215 for the 87.

For further information contact:
Universal Instrument Services Ltd, Unit 62, GEC Site, Cambridge Road, Whetstone, Leicester LE8 3LH. Tel: 0533 750123.

## POCKET LAB TEST

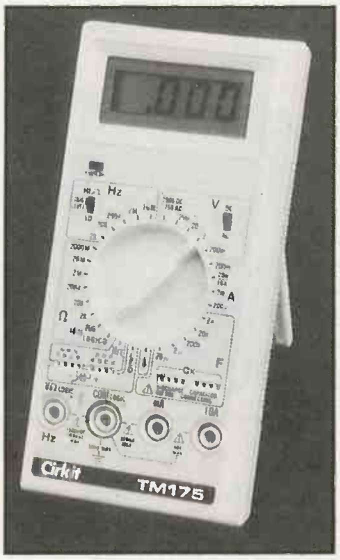
Fix new pocket-size digital multimeters are now available from Cirkit which offer a combination of facilities previously found only on larger, more expensive units.

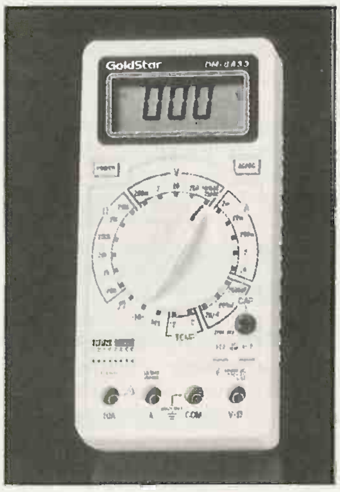
With prices starting at under £20, TM multimeters range from the basic TM5315B unit - featuring dc and ac voltage ranges, dc current measurement, resistance measurement, plus continuity and diode test, a basic 0.8% accuracy - to the advanced but economically priced model TM175, described by Cirkit as "the test lab in the pocket".

For users requiring a unit for testing oscillators, clock and timing circuits, the model TM5375 with frequency measurement up to 20MHz is especially suitable. Continuity, diode and HFE test are also available on this unit, with overload protection on all ranges. The next model up, the TM5365, additionally features capacitance measurement from 2 to 20µF, and all models have low battery indication, auto zero and auto polarity display.

Transistor gain test, continuity and diode test, dc and ac voltage, dc and ac current up to 10A and resistance measurement are common features on the TM115, TM135 and TM175 models. The TM135 also enables temperature measurement in both °C and °F, while virtually every facility needed for all disciplines of fault finding and testing are combined in the top-of-the-range TM175. In addition to the full complement of ranges it features capacitance measurement from 2nF to 20µF, frequency measurement up to 10MHz, and continuity, diode, HFE, logic and led test facilities.

Robustly constructed, TM series multimeters are housed in tough yellow ABS cases and are all supplied with a full one year warranty, test leads (TM135 additionally comes with a temperature sensor), battery and manual.





## HOLD AND COLD DMM

The latest GoldStar 84 Series from Alpha also doubles as an accurate digital thermometer. Model DM 8433 can measure from -20°C to +150°C (-4°F to +302°F) with a temperature probe supplied with each instrument. Other advanced features include a separate battery compartment for easy and safe replacement without entering the primary case. An easy to use single rotary switch with distinct indexing selects all functions and ranges and is large enough to be operated by a gloved hand.

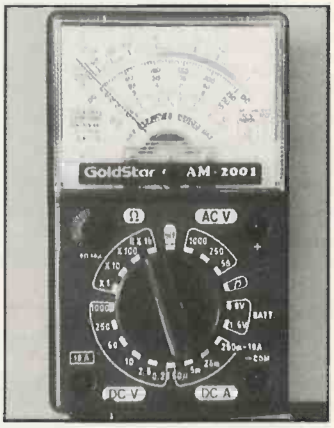
Large and clear, the 2000 count lcd indicates dc voltage to 1000V with a basic accuracy of 0.3% and ac voltage to 750V. Alternating and direct current are to 10A, resistance to 20M and capacitance to 20µF with a 1pF resolution. Other normal features are continuity with an audible tone, diode test and hFE measurement. Rugged and reliable the DM 8433 is manufactured from heavy duty plastic, guaranteed for 12 months and supplied ready for use with safety test leads, battery, spare fuse, operator's manual and temperature probe.

## ANALOGUE VALUE

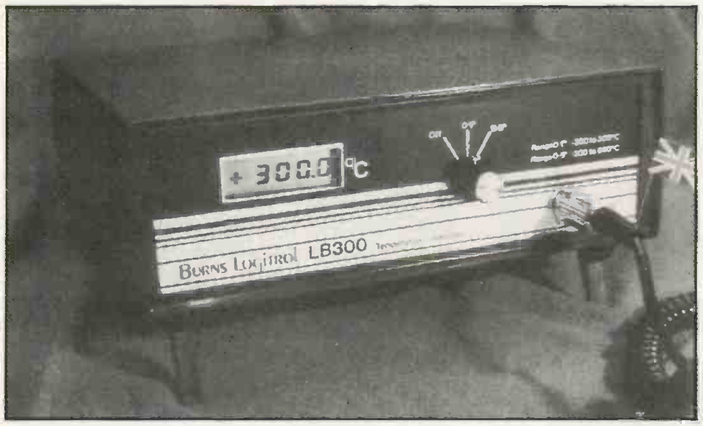
Don't ever think that analogue meters are outmoded by digital instruments. That's far from being the case and they have a powerful role to play in anyone's workshop.

The AM2001 is the latest analogue multimeter from Alpha Electronics and offers real value for money. Functions include ac and dc voltage, direct current, resistance, audible and visual continuity, battery test and a dB scale. Full protection with both fuse and diode make this hand held meter ideal for a host of general purpose applications.

Manufactured by GoldStar, the pivot and jewel meter has a mirrored scale to display dc and ac voltage to 1000V with sensitivities of 20k ohm/V and 8k ohm/V. Direct current is from 50mA to 10A in five useful ranges. The continuity mode is both instant and loud enough to be clearly heard in a noisy environment. Battery test positions for both 1.5V and 9V give instant colour coded indication of whether the cells under test are good or need replacing. Fully guaranteed and supplied ready for use in a carrying case, the AM 2001 measures 140 x 70 x 35 mm and weighs just 200gm including the internal hbattery. Its price is only £19.80, excluding VAt, but including a carrying case.



# NEWS



## BURNOMETER

A new platinum resistance thermometer has been launched by Burns Logitrol. The new LB300 benchtop unit has an extended range of accuracy when compared to similar priced products. Using standard PT100 sensors for reliable sensing, the meter has a crystal controlled analogue to digital convertor for consistent accuracy.

The LB300 has a resolution of 0.10° C over a -200° C to +300° C range; and 0.5 degree C resolution up to 850°C. With a basic accuracy of 0.1% the extended range and resolution make the LB300 ideal for monitoring many laboratory and manufacturing processes.

The thermometer features a 4 digit lcd display and a single range setting control. Normally powered by alkaline cells, the LB300 may also be supplied with rechargeable lead-acid batteries to allow extended periods of use without battery replacement. It is guaranteed for a period of two years, and the price is £170 excluding VAT and delivery.

## CAP IN HAND

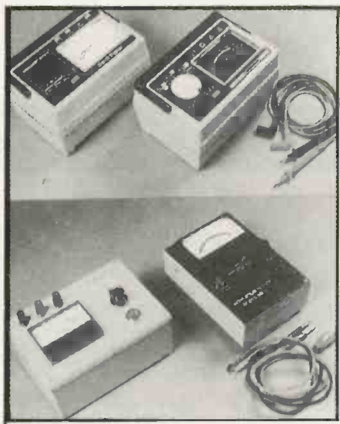
The new GDM 1.11 from Global Specialities is a 3.5-digit handheld multimeter which includes capacitance measurement as one of its eight functions.

The multimeter, which also includes diode testing and semiconductor hFE measurements, has a basic dc accuracy of 0.5%. The 29 ranges, which include dc voltage up to 1kV and dc/ac current up to 10A, are selected by a single rotary control. Probes are included in the purchase price of £49.95, and an optional carrying case is also available.

## Multi Measures

Two new instruments from TMK are simple, hand held, small, compact and very useful voltage testers. Ideal for general purpose use these new tools will carry out basic tests normally required by electricians.

Both models use two probes to measure ac and dc voltage to 440V in seven ranges with led indication and input protection to 500V. ElectroMate also indicates voltage polarity, has a diode and lamp check facility plus audible and visual continuity, weighs 150gm and measures 152 x 53 x 30m. VoltMate, the ultra low cost unit measures 185 x 32 x 22mm. Both are rugged and reliable, and are supplied ready for use complete with operating instructions. The prices are £33.75 for ElectroMate, and £4.95 for VoltMate.



**Photos: (Top) the genuine Megger instruments, (below) the potentially lethal fakes.**

## LETHAL MEGGER FAKES

Megger Instruments has sounded a world-wide alert following the discovery of potentially lethal pirate versions of two of its market leading earth and insulation testers.

The fakes are being manufactured in the Bombay factory of Indian company, Radiant Devices. Its first 'models' to come to light are the so called BM-12 insulation tester and the ET6/2-500 earth tester.

They were sold as genuine Megger instruments by a European multi-national company under the terms of a contract with an African government department. A summary inspection of the crudely copied instruments resulted in the arrest and detention of the multi-national's representative.

"The situation is extremely serious. These fakes could prove lethal," says Megger Instruments Marketing Director, Chris Burns.

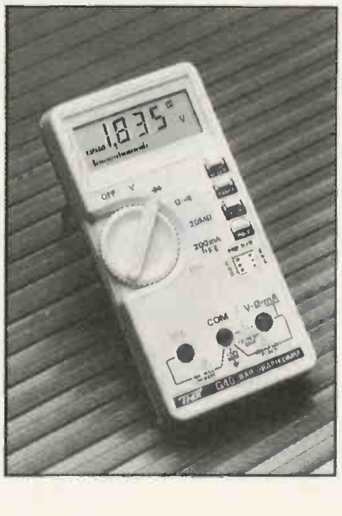
"We have uncovered a catalogue of faults that is nothing short of frightening and we intend to make every effort to see that this pirate trade is stamped out - and that includes a direct approach to the Indian High Commission."

So far none of the bogus instruments have appeared in the UK.

## Analogue and Digital

Another new instrument from TMK is a value for money digital multimeter for all general purpose applications and is housed in a rugged safety yellow case. Model G40 has a 3.5 digit liquid crystal display with full annunciation and an analogue bar graph to indicate the movement of unstable readings. Auto ranging is supplemented by manual range selection for readings of a similar value, a reading "hold" control and memory mode for carrying out relative measurements.

With a basic dc accuracy of 0.5% the G40 can accurately handle dc voltage to 1000V, ac voltage to 750V, both alternating and direct current to 10A and resistance to 20M. Other test modes include continuity with an audible tone, diode and hFE tests for both npn and pnp transistors. Fully guaranteed by TMK this latest dmm comes ready for use with an internal battery, test leads, instruction manual and a carrying case. Measuring 75 x 150 x 34mm, this useful hand held multimeter weighs just 230gms, and costs £65 plus vat.



## MAKING CONTACT

**Names and addresses for more information about the meters on these pages:**

**Alpha Electronics Ltd,** Unit 5,
Linstock Trading Estate, Wigan
Road, Atherton, Manchester M29
0QA. Tel: (0942) 873434

**Burns Logitrol,** Unit 1, Yeovil Small
Business Centre, Houndstone
Business Park, Yeovil, Somerset
BA22 8WA. Tel: (0935) 33529.

**Cirkit Distribution Ltd**, Park Lane,
Broxbourne, Herts EN10 7NQ. Tel:
(0992) 444111.

**Global Specialities**. 2nd Floor, 2 10
St. James Street, Bedford MK42
0DH. Tel: (0234) 217856.

**Megger Instruments Limited,**
Archcliffe Road, Dover, Kent CT17
9EN. Tel: (0304) 202620.

**TMK Instruments**, Building 3, GEC
Estate, East Lane, Wembley, Middx
HA9 7PJ Tel: 01-908 3355.

**Universal Instrument Services Ltd**.
Unit 62, GEC Site, Cambridge Road,
Whetstone, Leicester LE8 3LH. Tel:
(0533) 750123.

# CELLULAR EAVESDROPPING

### BY BARRY FOX
Winner of the
UK Technology Award

## It's 'nobody's job' to put a stop to telephone intruders.

Ever since Britain got a cellular radio service, in January 1985, there has been talk of outsiders eavesdropping on calls.

At first sight it seems obvious and easy; any telephone call that relies on a radio link must be open to reception by third parties. But a closer look suggests that listening-in may not be so easy, after all. Cell radio relies on frequencies in the uhf band, above tv, at nearly 1 GHz. Very few radios tune this high. Also the two halves of a conversation, to and from the mobile phone, are carried on quite different radio frequencies. And these frequencies change as the caller moves between cells.

## DISTASTEFUL

Also there had been a widespread feeling that eavesdropping is illegal as well as morally distasteful. So, on the whole, the press has played down the idea. Until recently, that is.

During 1989 there was a spate of articles glorifying the practice, as a hobby, and telling what equipment is needed and how much it costs. *(Not by PE, it hasn't! Ed)*

Now the awful truth has dawned. The law may not be as strong as assumed. And whatever the strength of the law, it is worthless unless upheld by those with responsibility to do so. Because responsibility is shared, the buck is being passed round.

So eavesdropping is fast becoming a consumer fad. The press are now even publishing transcripts of juicy dialogue between bankers, lawyers and illicit lovers.

## SCANDALOUS

"It is a scandal," says John Baylis of the Telecommunication Users Association. "Cellphone users are very worried and we have made official representations to the service operators Cellnet and Vodafone, and to Oftel, the Office of Telecommunications. But nothing has yet been done".

"The cellular industry is a law unto itself, it is not accountable to anybody", says Nicholas Michaelson, Chairman of the Cellular Phone Users Association. "The industry's aim is to make as much money as possible.

"Nearly 700,000 subscribers are each paying 25 pounds a month network fee, in addition to the 33p plus vat per minute it costs to make calls in London.

"Cellnet and Vodafone are too busy counting their money. They are treating a professional business tool like soap powder. Oftel is just a watch dog with rubber teeth, and very soft rubber at that".

When Cellnet, controlled by British Telecom, and Vodafone, owned by Racal, launched their cellphone services in January 1985 on the 900 MHz band, radio enthusiasts, with wide range receivers soon found that they could easily listen in. To their surprise they heard both halves of conversations, even though they are carried on separate frequencies. This is because the cellphone call passes through the public telephone network and both halves mix, to let callers hear in their ear piece what they speak into their mouthpiece.

## UNDETECTABLE

Eavesdropping is undetectable unless listeners publicise their actions. Licensed radio amateurs know that the Wireless Telegraphy Acts carry heavy fines and jail sentences for misuse of the airwaves. And they risk losing their licences. So they stay clear (usually) and have been nervous even of reporting overhead criminal conversations, for fear of laying themselves open to prosecution. Newspaper articles have tended to warn cellphone users about the risks of eavesdropping, rather than puff the vicarious thrill of listening to other people's personal secrets.

In the spring of 1989 things changed. A run of articles, culminating in a feature published by The Guardian (July 14) and re-printed by the Daily Mail (5 August) made eavesdropping sound like fun and quoted verbatim from numerous conversations overheard.

"I listen in on other people's phone conversations", confessed the Mail author "It's a hobby I really should be ashamed of and I suppose I would be if it didn't bring me so much pleasure".

I asked British Telecom about the new hobby. "We are concerned, but how can we stop it? Our view has always been that no telephone conversation is secure" was all BT could muster.

Oftel took a similar line: "It's regrettable. We believe it is an offence under the Telecommunications Act. But there is very little anyone can do about it."

Racal told me: "We are concerned" and cited at least six other articles this year, in addition to discussions on radio. But what was Racal actually doing about it?

Nothing.

Cellnet said it is taking legal advice and issued a weedy statement: "It is our understanding that listening-in to cellular telephone conversations contravenes the Interception of Communications Act 1985".

A week later Cellnet had been unable to say what it actually planned to do.

## BUCKPASSING

The Department of Trade and Industry thought it was not illegal under the Wireless Telegraphy Acts to listen-in, only to use any information obtained. The DTI told me it had no plans to prosecute and believed the best remedy lies with the Interception of Communications Act, 1985 for which the Home Office is responsible.

The Home Office told me it thought that any eavesdropping, whether by wire or radio, contravenes its Act with unlimited fines and up to two years in jail. But would the Home Office be doing anything? No, that was up to the police.

So, while the buck passes round in circles, shops are cashing in on the sale of radio receivers which can receive the cell phone channels..

Eavesdropping might turn out to be the best cure yet for congestion of the airwaves. Any cellphone user with a confidential a call to make will go back to using an old-fashioned fixed phone. PE

PRACTICAL
ELECTRONICS

# STARTING TERMS

As we enter the new decade with this January issue, I am filled with excitement over what new developments in technology we shall experience over the next ten years. I am additionally conscious of the number of decades that have passed (no, I'm not disclosing numbers!) since I first became aware that electricity need not be lethal and could, with the right approach, be tamed.

Early experiments involved little more than adding jack sockets to various radio units to permit tape recording without a microphone interface. Usually, these improvements were well within pocket money budgets, and their success prompted more adventurous endeavours. On occasion, though, erroneous logic crept in and the knowledge gained became expensive, like the time I discovered that loudspeakers don't like mains current carelessly shorted across them, especially when they're part of father's deluxe gramophone!

In those days, though, the only way I knew how to learn about electricity was by trial and error. No-one told me how to learn more in an academic way. With hindsight, I know now that there were magazines and books around, and I wish that their existence had been brought to my attention. The school, good as it was in many ways regarding science, never told me about *electronics*, indeed I don't recall the term ever being used, the whole subject seemed to be regarded simply as *wireless*.

Because for many years I learned the hard way until eventually becoming assisted by the tutorials in PE, I am extremely conscious of the educational role that PE can play. Experimenting is enormous fun but, before one becomes greatly experienced, it can be even more rewarding if assisted by high class tutors who can tell you not only what you might try, but also the reasons for things working as they do.

It's not my intention now to comment on technology education in today's schools (though from the letters I receive I am prompted to do so sometime in the future), but I know that many teachers and students will greatly benefit from the new series starting this month. The series is aptly called *Basic Electronics* and thoroughly covers the principle aspects of the theory of how and why electronics works, the nature of the components that are in common use, and many of the different ways in which they can be put together to cater for particular applications. At various stages throughout the series, simple constructional projects will accompany the text, illustrating the ideas discussed.

It's a series that will be of tremendous value to anyone who is only just becoming interested in electronics. It will also serve as an excellent refresher course even for those readers who have already found themselves addicted to electronics. Who amongst you can truthfully say that you are fully conversant with all the basic principles? Even I've been reminded of one or two things I'd forgotten!

The author, Owen Bishop, is a top class tutor of international renown. His qualifications are far too lengthy to list, but he has been closely associated with education for many years and has written a vast quantity of books on electronics and computing. His name will, of course, be familiar to many PE readers since we have only recently completed his informative series on *Digital Electronics*.

And from the Bishop, on to Christmas! It may be January on the cover, but you'll probably read this during December, so from all of us on PE and at Intra Press, Happy Season's Greetings!

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All editorial correspondence should be addressed to the editor and **any letters requiring a reply should be accompanied by a stamped addressed envelope, or equivalent payment.**

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Cover Photo:
Global Specialities GDM1-11, handheld digital multimeter

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| 7433 | 0.30 |
| 7437 | 0.30 |
| 7438 | 0.40 |
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| 74111 | 0.56 |
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| 74119 | 1.70 |
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| 74123 | 0.80 |
| 74125 | 0.66 |
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| 74173 | 1.40 |
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| 74176 | 1.00 |
| 74178 | 1.50 |
| 74179 | 1.50 |
| 74180 | 1.00 |
| 74181 | 3.40 |
| 74182 | 1.40 |
| 74184 | 1.80 |
| 74185A | 1.80 |
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| 74191 | 1.30 |
| 74192 | 1.10 |
| 74193 | 1.15 |
| 74194 | 1.10 |
| 74195 | 0.80 |
| 74196 | 1.30 |
| 74197 | 1.10 |
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| 74199 | 2.20 |
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| 74251 | 1.00 |
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| 74265 | 0.80 |
| 74273 | 2.00 |
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| 74278 | 1.70 |
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| 74LS30 | 0.24 |
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| 74LS93 | 0.54 |
| 74LS95B | 0.75 |
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| 74LS107 | 0.40 |
| 74LS109 | 0.40 |
| 74LS112 | 0.45 |
| 74LS113 | 0.45 |
| 74LS114 | 0.45 |
| 74LS122 | 0.70 |
| 74LS123 | 0.80 |
| 74LS124 | 1.40 |
| 74LS125 | 0.50 |
| 74LS126 | 0.50 |
| 74LS132 | 0.65 |
| 74LS133 | 0.50 |
| 74LS136 | 0.45 |
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| 74LS147 | 1.75 |
| 74LS148 | 1.40 |
| 74LS151 | 0.65 |
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| 74LS155 | 0.65 |
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| 74LS157 | 0.50 |
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| 74LS197 | 0.80 |
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| 74LS240 | 0.90 |
| 74LS241 | 0.90 |
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| 74LS243 | 0.90 |
| 74LS244 | 0.70 |
| 74LS245 | 0.90 |
| 74LS247 | 1.10 |
| 74LS248 | 1.10 |
| 74LS249 | 1.10 |
| 74LS251 | 0.75 |
| 74LS253 | 0.75 |
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| 74LS257A | 0.70 |
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| 74LS259 | 1.20 |
| 74LS260 | 0.75 |
| 74LS261 | 1.20 |
| 74LS266 | 0.60 |
| 74LS273 | 1.25 |
| 74LS279 | 0.70 |
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| 74LS283 | 0.80 |
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| 74LS352 | 1.20 |
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| 74LS356 | 2.10 |
| 74LS363 | 1.80 |
| 74LS364 | 1.80 |
| 74LS365 | 0.50 |
| 74LS366 | 0.50 |
| 74LS367 | 0.52 |
| 74LS368 | 0.50 |
| 74LS373 | 0.70 |
| 74LS374 | 0.70 |
| 74LS375 | 0.75 |
| 74LS377 | 1.30 |
| 74LS378 | 0.95 |
| 74LS379 | 1.30 |
| 74LS381 | 4.50 |
| 74LS390 | 0.60 |
| 74LS393 | 1.00 |
| 74LS395A | 1.00 |
| 74LS399 | 1.40 |
| 74LS445 | 1.80 |
| 74LS465 | 1.20 |
| 74LS467 | 1.80 |
| 74LS540 | 1.00 |
| 74LS541 | 1.00 |
| 74LS608 | 7.00 |
| 74LS610 | 25.00 |
| 74LS612 | 25.00 |
| 74LS624 | 3.50 |
| 74LS626 | 2.25 |
| 74LS628 | 2.25 |
| 74LS629 | 1.25 |
| 74LS640 | 2.00 |
| 74LS640-1 | 3.00 |
| 74LS641 | 1.50 |
| 74LS642 | 2.50 |
| 74LS642-1 | 3.00 |
| 74LS643 | 2.50 |
| 74LS643-1 | 3.00 |
| 74LS644 | 3.50 |
| 74LS645 | 2.00 |
| 74LS645-1 | 4.00 |
| 74LS668 | 0.90 |
| 74LS669 | 0.90 |
| 74LS670 | 1.70 |
| 74LS682 | 2.50 |
| 74LS684 | 3.50 |
| 74LS687 | 3.50 |
| 74LS688 | 3.50 |
| 74C922 | 6.00 |
| 74C923 | 6.50 |
| 74C925 | 6.50 |
| 74C926 | 6.50 |

### 4000 SERIES

| | |
|---|---|
| 4000 | 0.20 |
| 4001 | 0.24 |
| 4002 | 0.25 |
| 4006 | 0.70 |
| 4007 | 0.25 |
| 4008 | 0.60 |
| 4009 | 0.45 |
| 4010 | 0.60 |
| 4011 | 0.24 |
| 4012 | 0.25 |
| 4013 | 0.36 |
| 4014 | 0.60 |
| 4015 | 0.70 |
| 4016 | 0.36 |
| 4017 | 0.55 |
| 4018 | 0.60 |
| 4019 | 0.60 |
| 4020 | 0.80 |
| 4021 | 0.60 |
| 4022 | 0.70 |
| 4023 | 0.30 |
| 4024 | 0.48 |
| 4025 | 0.24 |
| 4026 | 0.90 |
| 4027 | 0.40 |
| 4028 | 0.60 |
| 4029 | 0.75 |
| 4030 | 0.35 |
| 4031 | 1.25 |
| 4032 | 1.00 |
| 4033 | 1.25 |
| 4034 | 2.50 |
| 4035 | 0.70 |
| 4036 | 2.50 |
| 4037 | 1.10 |
| 4038 | 1.00 |
| 4039 | 2.50 |
| 4040 | 0.60 |
| 4041 | 0.56 |
| 4042 | 0.50 |
| 4043 | 0.60 |
| 4044 | 0.60 |
| 4045 | 1.00 |
| 4046 | 0.60 |
| 4047 | 0.60 |
| 4048 | 0.55 |
| 4049 | 0.36 |
| 4050 | 0.35 |
| 4051 | 0.65 |
| 4052 | 0.60 |
| 4053 | 0.60 |
| 4054 | 0.80 |
| 4055 | 0.80 |
| 4056 | 0.85 |
| 4059 | 4.00 |
| 4060 | 0.70 |
| 4063 | 0.85 |
| 4066 | 0.40 |
| 4068 | 0.25 |
| 4069 | 0.24 |
| 4070 | 0.24 |
| 4071 | 0.24 |
| 4072 | 0.24 |
| 4073 | 0.24 |
| 4075 | 0.24 |
| 4076 | 0.65 |
| 4077 | 0.25 |
| 4078 | 0.25 |
| 4081 | 0.24 |
| 4082 | 0.25 |
| 4085 | 0.60 |
| 4086 | 0.75 |
| 4089 | 1.20 |
| 4093 | 0.35 |
| 4094 | 0.90 |
| 4095 | 0.90 |
| 4096 | 0.90 |
| 4097 | 2.70 |
| 4098 | 0.75 |
| 4099 | 0.90 |
| 4501 | 0.36 |
| 4502 | 0.55 |
| 4503 | 0.36 |
| 4504 | 0.95 |
| 4505 | 3.60 |
| 4506 | 0.90 |
| 4507/4030 | 0.35 |
| 4508 | 1.20 |
| 4510 | 0.55 |
| 4511 | 0.56 |
| 4512 | 0.55 |
| 4513 | 1.50 |
| 4514 | 1.10 |
| 4515 | 1.10 |
| 4516 | 0.55 |
| 4517 | 2.20 |
| 4518 | 0.48 |
| 4519 | 0.32 |
| 4520 | 0.60 |
| 4521 | 1.15 |
| 4522 | 0.80 |
| 4526 | 0.70 |
| 4527 | 0.80 |
| 4528 | 0.65 |
| 4529 | 1.00 |
| 4531 | 0.75 |
| 4532 | 0.65 |
| 4534 | |
| 4536 | 2.50 |
| 4538 | 0.75 |
| 4539 | 0.75 |
| 4541 | 0.90 |
| 4543 | 0.70 |
| 4551 | 1.00 |
| 4553 | 2.40 |
| 4555 | 0.36 |
| 4556 | 0.50 |
| 4557 | 2.40 |
| 4560 | 1.40 |
| 4566 | 1.40 |
| 4568 | 2.40 |
| 4569 | 1.70 |
| 4572 | 0.45 |
| 4583 | 0.90 |
| 4584 | 0.48 |
| 4585 | 0.60 |
| 4724 | 1.50 |
| 14411 | 7.50 |
| 14412 | 7.50 |
| 14416 | 3.00 |
| 14419 | 2.60 |
| 14490 | 4.20 |
| 14495 | 4.50 |
| 14500 | 6.50 |
| 14599 | 2.00 |
| 22100 | 3.50 |
| 22101 | 7.00 |
| 22102 | 7.00 |
| 40014 | 0.48 |
| 40085 | 1.20 |
| 40097 | 0.36 |
| 40098 | 0.40 |
| 40100 | 1.50 |
| 40101 | 1.25 |
| 40102 | 1.50 |
| 40103 | 2.00 |
| 40104 | 1.20 |
| 40105 | 1.50 |
| 40106 | 0.48 |
| 40107 | 0.55 |
| 40108 | 3.20 |
| 40109 | 1.20 |
| 40110 | 2.25 |
| 40114 | 2.25 |
| 40147 | 2.80 |
| 40163 | 1.00 |
| 40173 | 1.20 |
| 40174 | 1.00 |
| 40175 | 1.00 |
| 40192 | 1.00 |
| 40193 | 1.00 |
| 40194 | 1.00 |
| 40244 | 1.50 |
| 40245 | 1.50 |
| 40257 | 1.80 |
| 40373 | 1.80 |
| 40374 | 1.80 |
| 80C95 | 0.75 |
| 80C97 | 0.75 |
| 80C98 | 0.75 |

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### zif sockets

| | |
|---|---|
| 24 pin | 5.50 |
| 28 pin | 7.00 |
| 40 pin | 8.00 |

### TL & ECL

| | |
|---|---|
| 10116 | 70p |
| 10231 | 350p |

## LINEAR ICs

| | |
|---|---|
| AD7581 | 12.00 |
| ADC0808 | 11.90 |
| AM7910DC | 25.00 |
| AN103 | 2.00 |
| AY1 5050 | 1.00 |
| AY3 8010 | 4.50 |
| AY3 8910 | 4.50 |
| AY3 8912 | 5.00 |
| CA3019A | 1.00 |
| CA3028A | 1.10 |
| CA3046 | 0.70 |
| CA3059 | 3.20 |
| CA3060 | 3.50 |
| CA3080E | 0.70 |
| CA3086 | 0.60 |
| CA3089E | 2.50 |
| CA3090AQ | 3.75 |
| CA3130E | 0.90 |
| CA3130T | 1.30 |
| CA3140E | 0.45 |
| CA3140T | 1.00 |
| CA3146 | 2.25 |
| CA3160E | 1.50 |
| CA3161E | 2.00 |
| CA3162E | 6.00 |
| CA3189E | 2.70 |
| CA3240E | 1.50 |
| CA3280G | 3.00 |
| D7002 | 6.00 |
| DAC1408 8 | 3.00 |
| DAC0800 | 3.00 |
| DAC0808 | 3.00 |
| DG308 | 3.00 |
| HA1366 | 1.90 |
| ICL7106 | 6.75 |
| ICL7611 | 0.95 |
| ICL7650 | 4.00 |
| ICL7660 | 2.50 |
| ICL8038 | 4.00 |
| ICM7555 | 0.90 |
| ICM7556 | 1.40 |
| LC7120 | 3.00 |
| LC7130 | 3.00 |
| LC7431 | 3.50 |
| LC7137 | 3.50 |
| LF347 | 1.20 |
| LF351 | 0.60 |
| LF353 | 0.90 |
| LF355 | 0.90 |
| LF356N | 1.10 |
| LF357 | 1.00 |
| LM10CLH | 4.50 |
| LM301A | 0.30 |
| LM307 | 0.45 |
| LM308CN | 0.75 |
| LM310 | 2.25 |
| LM311 | 0.60 |
| LM318 | 1.50 |
| LM319 | 1.80 |
| LM324 | 0.45 |
| LM334Z | 1.15 |
| LM335Z | 1.30 |
| LM336 | 1.60 |
| LM339 | 0.40 |
| LM348 | 0.60 |
| LM349CH | 3.60 |
| LM358P | 0.50 |
| LM377 | 3.00 |
| LM380N-8 | 1.50 |
| LM380N | 1.50 |
| LM381N | 3.00 |
| LM382 | 2.00 |
| LM383 | 3.25 |
| LM384 | 2.20 |
| LM386N 1 | 1.00 |
| LM387 | 2.70 |
| LM391 | 1.80 |
| LM392N | 1.10 |
| LM393 | 0.85 |
| LM394CH | 4.00 |
| LM709 | 0.35 |
| LM710 | 0.48 |
| LM711 | 1.00 |
| LM723 | 0.60 |
| LM725CN | 4.00 |
| LM733 | 0.65 |
| LM741 | 0.22 |
| LM747 | 0.70 |
| LM748 | 0.30 |
| LM1011 | 4.80 |
| LM1014 | 1.50 |
| LM1801 | 3.00 |
| LM1830 | 2.50 |
| LM1871 | 3.00 |
| LM1872 | 3.00 |
| LM1886 | 6.00 |
| LM1889 | 4.50 |
| LM2917 | 3.00 |
| LM3302 | 0.90 |
| LM3900 | 0.80 |
| LM3909 | 1.00 |
| LM3911 | 1.80 |
| LM3914 | 3.50 |
| LM3915 | 3.40 |
| LM3916 | 3.40 |
| LM13600 | 1.50 |
| M51513L | 2.30 |
| M51516L | 4.50 |
| MB3712 | 2.00 |
| MC1310 | 1.50 |
| MC1413 | 0.75 |
| MC1458 | 0.45 |
| MC1495L | 3.00 |
| MC1496 | 0.70 |
| MC3340 | 2.00 |
| MC3401 | 0.70 |
| MC3403 | 0.65 |
| MF10CN | 4.00 |
| MK50240 | 9.00 |
| ML920 | 5.00 |
| ML922 | 4.00 |
| MM66221A | 3.00 |
| NE531 | 1.20 |
| NE555 | 0.22 |
| NE556 | 0.60 |
| NE564 | 4.00 |
| NE565 | 1.20 |
| NE566 | 1.50 |
| NE567 | 1.25 |
| NE570 | 4.00 |
| NE571 | 3.00 |
| NE592 | 0.90 |
| NE5532P | 1.50 |
| NE5533P | 1.60 |
| NE5534P | 1.20 |
| NE5534AP | 1.50 |
| OP 07EP | 3.50 |
| PLL02A | 5.00 |
| RC4136 | 0.55 |
| RC4151 | 2.00 |
| RC4195 | 1.50 |
| RC4558 | 0.55 |
| S50240 | 9.00 |
| SAA1900 | 16.00 |
| SFF96364 | 8.00 |
| SL490 | 3.00 |
| SN76033N | 3.00 |
| SN76489 | 4.00 |
| SN76495 | 4.00 |
| SN76660 | 1.20 |
| SPO256AL2 | 7.00 |
| TA7120 | 1.20 |
| TA130 | 1.40 |
| TA7204 | 1.50 |
| TA7205 | 0.90 |
| TA7222 | 1.50 |
| TA7310 | 1.50 |
| TBA231 | 1.20 |
| TBA800 | 0.80 |
| TBA810 | 0.90 |
| TBA820 | 0.80 |
| TBA820M | 0.75 |
| TBA920 | 2.00 |
| TBA950 | 2.25 |
| TC9109 | 5.00 |
| TCA940 | 1.75 |
| TDA1010 | 2.25 |
| TDA1022 | 4.50 |
| TDA1024 | 1.10 |
| TDA1170S | 3.00 |
| TDA2002 | 3.25 |
| TDA2003 | 1.90 |
| TDA2004 | 2.40 |
| TDA2006 | 3.20 |
| TDA2020 | 3.20 |
| TDA2030 | 2.50 |
| TDA3810 | 7.50 |
| TDA7000 | 3.50 |
| TEA1002 | 7.00 |
| TL061CP | 0.40 |
| TL062 | 0.60 |
| TL064 | 0.90 |
| TL071 | 0.40 |
| TL072 | 0.70 |
| TL074 | 1.10 |
| TL081 | 0.35 |
| TL082 | 0.55 |
| TL083 | 0.75 |
| TL084 | 1.00 |
| TL094 | 2.00 |
| UA759 | 3.20 |
| UA2240 | 1.50 |
| UCN5801A | 6.00 |
| ULN2003A | 0.75 |
| ULN2004A | 0.75 |
| ULN2068 | 2.90 |
| ULN2802 | 1.90 |
| ULN2803 | 1.80 |
| ULN2804 | 1.90 |
| UPC575 | 2.75 |
| UPC592H | 2.00 |
| UPC1156H | 3.00 |
| UPC1185H | 5.00 |
| XR210 | 4.00 |
| XR2206 | 4.00 |
| XR2207 | 3.75 |
| XR2211 | 5.75 |
| XR2216 | 6.75 |
| XR2240 | 1.20 |
| ZN404 | 1.00 |
| ZN414 | 0.80 |
| ZN419P | 1.75 |
| ZN423E | 1.30 |
| ZN424E | 1.30 |
| ZN425E8 | 3.50 |
| ZN426E8 | 3.00 |
| ZN427E8 | 6.00 |
| ZN428E8 | 4.50 |
| ZN429E8 | 2.25 |
| ZN447E | 9.00 |
| ZN448 | 7.50 |
| ZN449E | 3.00 |
| ZN450E | 7.50 |
| ZN459CP | 3.00 |
| ZN1034E | 2.00 |
| ZN1040 | 6.60 |
| ZNA134H | 23.00 |
| ZNA234E | 9.50 |

## VOLTAGE REGULATORS

### 1A FIXED VOLTAGE PLASTIC TO220

| + VE | | | – VE | |
|---|---|---|---|---|
| 5 V | 7805 | 0.45 | 7905 | 0.50 |
| 6 V | 7806 | 0.50 | 7906 | 0.50 |
| 8 V | 7808 | 0.50 | 7908 | 0.50 |
| 12 V | 7812 | 0.45 | 7912 | 0.50 |
| 15 V | 7815 | 0.50 | 7915 | 0.50 |
| 18 V | 7818 | 0.50 | 7918 | 0.60 |
| 24 V | 7024 | 0.50 | 7924 | 0.50 |

### .1A FIXED VOLTAGE PLASTIC TO92

| | | | | | |
|---|---|---|---|---|---|
| 5 V | 78L05 | 0.30 | 15 V | 78L15 | 0.30 |
| 6 V | 78L06 | 0.30 | 5 V | 79L05 | 0.45 |
| 8 V | 78L08 | 0.30 | 12 V | 79L12 | 0.50 |
| 12 V | 78L12 | 0.30 | 15 V | 17L15 | 0.50 |

### OTHER REGULATORS

| | |
|---|---|
| LM309K | 1.40 |
| LM323K | 2.50 |
| 78HO5KC<br>5 A 5 V | 5.75 |
| 78H12 | 7 50 |

### SWITCHING REGULATORS

| | |
|---|---|
| ICL7660 | 2.50 |
| SG3524 | 3.00 |
| TL494 | 3.00 |
| TL497 | 2.25 |
| 78S40 | 2.50 |
| RC4195 | 1.50 |

### VARIABLE REGULATORS

| | | | |
|---|---|---|---|
| LM305AH | 2.50 | LM723N | 0.50 |
| LM317T | 1.20 | 78HGKC | 6.50 |
| LM317K | 2.40 | 78GUIC | 2.25 |
| LM337T | 2.25 | 79HGKC | 6.75 |
| LM350T | 4.00 | 79GUIC | 2.50 |
| LM396K | 15.00 | 79MGT2C | 1.40 |

### OPTO ISOLATORS

| | | | |
|---|---|---|---|
| ILD74 | 1.30 | TIL112 | 0.70 |
| ILQ74 | 2.20 | TIL113 | 0.70 |
| MCT26 | 1.00 | TIL116 | 0.70 |
| MCS2400 | 1.90 | 6N137 | 3.60 |
| MOC3020 | 1.50 | 6N139 | 1.75 |
| TIL111 | 0.70 | | |

### DISPLAYS

| | | | |
|---|---|---|---|
| FND357 | 1.00 | MAN6610 | 2.00 |
| FND500 TIL730 | 1.00 | NSB5881 | 5.70 |
| FND507 TIL729 | 1.00 | TIL311 | 6.50 |
| MAN74 DL704 | 1.00 | TIL729 | 1.00 |
| MAN71 DL707 | 1.00 | TIL730 | 1.00 |
| MAN3640 | 1.75 | MAN8910 | 1.50 |
| MAN4640 | 2.00 | | |

### DISPLAY DRIVERS

| | | | |
|---|---|---|---|
| 9368 | 4.50 | ULN2003 | 0.90 |
| 9370 | 4.50 | ULN2004 | 0.90 |
| 9374 | 3.50 | ULN2068 | 2.90 |
| LM3914 | 3.50 | ULN2802 | 1.90 |
| LM3915 | 3.50 | ULN2803 | 1.80 |
| LM3916 | 3.50 | ULN2804 | 1.90 |
| UDN6118 | 3.20 | 75491 | 0.70 |
| UDN6184 | 3.20 | 75492 | 0.70 |

### OTHERS

| | | | |
|---|---|---|---|
| 2N5777 | 0.50 | ORP12 | 1.20 |
| BPX25 | 1.80 | ORP60 | 1.20 |
| BPW21 | 2.80 | ORP61 | 1.20 |
| OCP71 | 1.80 | SFH205 | 1.00 |

***ATTENTION***
**ALL PRICES ARE SUBJECT TO CHANGE WITHOUT NOTICE**

### SCRS

| | |
|---|---|
| 1A 50V | 70p |
| 5A 400V | 50p |
| 8A 600V | 140p |
| 16A 100V | 200p |
| C106D | 45p |
| MCR101 | 36p |
| TIC44 | 36p |
| 2N3525 | 130p |
| 2N4444 | 140p |
| 2N5060/4 | 40p |

### ZENERS

2.7V 33V

| | |
|---|---|
| 400MW | 9p |
| 1W | 15p |

### TRIACS

Plastic

| | |
|---|---|
| 3A 400V | 60p |
| 6A 400V | 70p |
| 6A 500V | 90p |
| 8A 400V | 75p |
| 8A 500V | 95p |
| 12A500V | 105p |
| 16A500V | 130p |
| T 2800D | 130p |
| T1206D | 50p |
| T1226D | 70p |

### DISCRETE DISPLAYS LEDS

| | |
|---|---|
| 125" | |
| RED TIL209 | 0.12 |
| GREEN TIL211 | 0.15 |
| YELLOW TIL212 | 0.20 |
| Rect LEDs (R G Y) | 0.30 |
| CXQ (B) Colour | 1.00 |
| 10 LED Bargraph: | |
| Red | 2.25 |
| Green | 2.25 |
| 0.2" | |
| TIL220 | 0.15 |
| TIL222 | 0.18 |
| TIL226 | 0.22 |
| TIL32 | 0.55 |
| TIL78 | 0.55 |
| TIL31B | 1.20 |
| TIL81 | 1.20 |
| TIL100 | 0.75 |

## CPU's

| | |
|---|---|
| 68B09 | 10.00 |
| 68B09E | 12.00 |
| 8035 | 3.50 |
| 8039 | 4.20 |
| 80C39 | 7.00 |
| 8080A | 7.50 |
| 8085A | 3.00 |
| 80C85A | 9.00 |
| 8086 | 22.00 |
| 8087-5 | £70 |
| 8087-8 | £96 |
| 80287-8 | £155 |
| 80287-10 | £175 |
| 8088 | 17.50 |
| 8741 | 12.00 |
| 8748 | 12.00 |
| TMS9980 | 14.50 |
| TMS9995 | 18.00 |
| Z80 | 2.50 |
| Z80A | 2.90 |
| Z80B | 5.50 |
| 70008 | 7.50 |

### SUPPORT DEVICES

| | |
|---|---|
| 2651 | 12.00 |
| 2816-30 | 20.00 |
| 3242 | 8.00 |
| 3245 | 4.50 |
| 6520 | 3.00 |
| 6522 | 3.50 |
| 6522A | 5.50 |
| 6532 | 4.80 |
| 6551A | 5.50 |
| 6821 | 1.80 |
| 68B21 | 3.00 |
| 6829 | 12.50 |
| 6840 | 3.75 |
| 68B40 | 6.00 |
| 6850 | 1.80 |
| 68B50 | 3.00 |
| 6852 | 2.50 |
| 6854 | 6.50 |
| 68B54 | 8.00 |
| 6875 | 5.00 |
| 8154 | 8.50 |
| 8155 | 3.80 |
| 8156 | 3.80 |
| 8205 | 2.25 |
| 8212 | 2.20 |
| 8216 | 1.60 |
| 8224 | P.O.A. |
| 8226 | 4.25 |
| 8228 | 5.50 |
| 8243 | 2.60 |
| 8250 | 12.00 |
| 8251A | 3.25 |
| 8253C-5 | 3.50 |
| 8255AC-5 | 3.20 |
| 8256 | 18.00 |
| 8257C-5 | 4.00 |
| 8259C-5 | 4.00 |
| 8275 | 29.00 |
| 8279C-5 | 4.80 |
| 8282 | 3.00 |
| 8283 | 4.00 |
| 8284 | 4.50 |
| 8287 | 3.80 |
| 8288D | 6.50 |
| 8755A | |
| 0 1 2 9 | 16.00 |
| TMS4500 | 14.00 |
| TMS9901 | 5.00 |
| TMS9902 | 5.00 |
| TMS9911 | 18.00 |
| TMS9914 | 14.00 |
| Z80P10 | 2.50 |
| Z80AP10 | 2.75 |
| Z80CTC | 2.50 |
| Z80ACTC | 2.75 |
| Z80DART | 6.50 |
| Z80ADART | 7.00 |
| Z80DMA | 7.00 |
| Z80ADMA | 7.50 |
| Z80ASIO | 7.00 |
| Z80BP10 | 5.00 |
| Z80BCTC | 5.00 |
| Z80BDART | 9.00 |

### CPU's

| | |
|---|---|
| 1802CE | 6.50 |
| 2650A | 10.50 |
| 6502 | 4.50 |
| 65C02-2MHz | 12.00 |
| 6502A | 6.50 |
| 6502B | 8.00 |
| 6800 | 2.50 |
| 6802 | 3.00 |
| 6803-2 | 12.00 |
| 6809 | 6.50 |
| 6809E | 10.00 |

## RAMS

| | |
|---|---|
| 2016-150 | 4.00 |
| 2101 | 4.00 |
| 2107B | 5.00 |
| 2111A-35 | 4.00 |
| 2114 | 1.50 |
| 2114-3 | 2.50 |
| 2147 | 4.00 |
| 4116-15 | 2.00 |
| 4116-20 | 1.50 |
| 4164-15 (TI) | 3.00 |
| 4164-15 | 1.50 |
| 4416-15 | 3.00 |
| 4532-20 | 2.50 |
| 41256-15 | 3.00 |
| 5101/5501 | 4.00 |
| 5514/5114 | 4.00 |
| 5516 | 4.00 |
| 5517 | 4.00 |
| 50256-15 | 4.00 |
| 5116LP-3 | 3.00 |
| 6264LP-15 | 2.60 |
| 5810 | 2.00 |
| 74S189 | 1.80 |
| 74S201 | 3.50 |
| 74S289 | 2.25 |
| 93415 | 6.00 |
| 93425 | 6.00 |

### ROMS/PROMS

| | |
|---|---|
| 28L22 | 4.00 |
| 24S10 | 2.50 |
| 18S030 | 2.00 |
| 18SA030 | 2.00 |
| 74S188 | 1.80 |
| 74S287 | 2.25 |
| 74S288 | 1.80 |
| 74S387 | 2.25 |
| 82S23 | 1.50 |
| 82S123 | 1.50 |
| 82S129 | 1.50 |

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| 16 pin | 11p | 22 pin | 22p | 40 pin | 30p |

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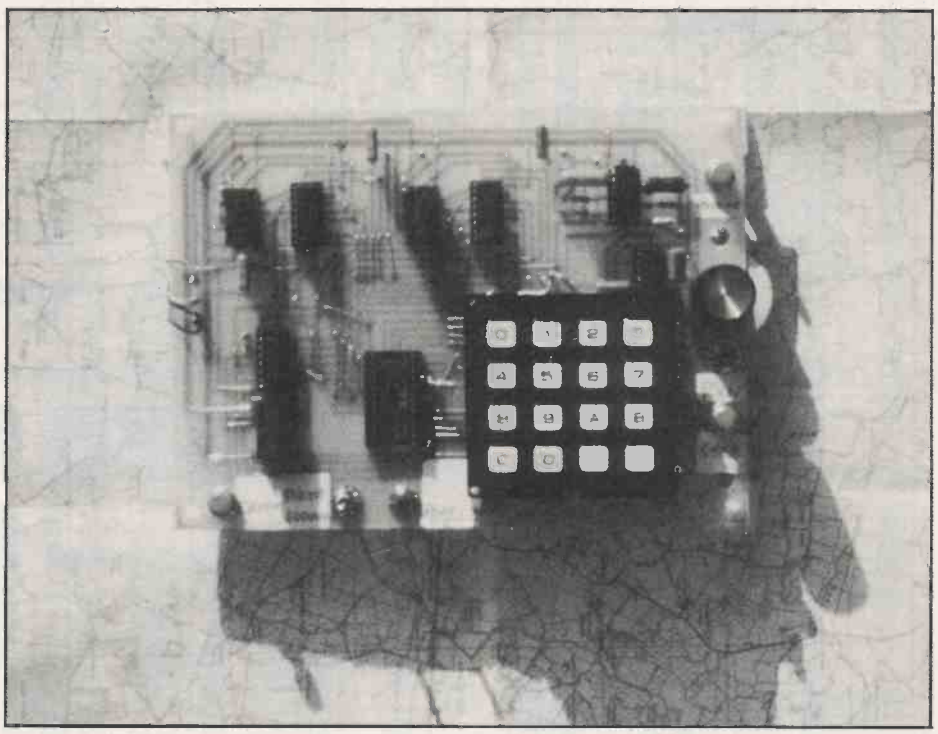
# EEPROM AND NVM PROGRAMMERS

By Malcolm Harvey

## Dabblers and devotees: open up new horizons for programmed projects!

Quite a few constructional projects are published in which an eprom memory device is used as part of the automatic control system. For many PE readers the programming of an eprom presents no difficulty, either because they already own a programmer, or have access to one through the company for which they work. There are, though, a significant number of readers who do not have access to a programmer and regard the cost of purchasing one as uneconomic compared to the number of times it is likely to be used.


The author's prototype of the keyboard controlled programmer.

## ERASING ECONOMICS

There is an additional problem regarding eprom programming since any code entered into the eprom is permanently stored and can only be removed by an ultraviolet eprom eraser unit. For the occasional would-be user, the purchase of an eraser is another expense that might be regarded as uneconomic. Furthermore, even if an eraser is owned, it is still an inconvenience to have to spend perhaps twenty or thirty minutes waiting for the eraser to complete its task.

Why should we need to erase a programmed eprom code? some of you may ask. There are two principal reasons: to amend a incorrect entry, or to make the eprom reusable for some other control function. The latter reason particularly applies to those who love experimenting and wish to try out different ideas without the delay caused by erasing, or the expense of holding a stock of spare eproms. The problem of incorrect data entry is one that mainly afflicts those who only possess a simple eprom programmer in which the data is entered directly and without a buffer memory. The frustration of getting nearly to the end of a lengthy chunk of code only to then make a mistake is obviously quite maddening, necessitating full erasure and starting from the beginning again!

## ALTERNATIVE PROMS

Among the eprom controlled projects published there are some for which exist alternative memory devices that do not require erasing by uv light and which can have individual code bits immediately changed without having to reprogram the full code sequence. The alternative devices are electrically erasable programmable read-only memories (eeprom or e2prom) and non-volatile memories (nvm) with an integral battery.

Eeproms, in addition to not requiring uv erasure, have a further advantage over standard eproms: they can be powered and programmed using a 5V power supply, whereas an eprom requires a separate higher-voltage programming supply in addition to the normal 5V supply.

The battery-backed nvms are more expensive than eproms or eeproms and have a lithium battery built into them which ensures that a programmed code is retained even when the main 5V power supply is turned off or the chip is removed from its socket. Typically, the lithium battery has a life of around three years in the absence of the main power supply.

The use of either of these alternative devices has immediate implications for those who, for whatever reason, do not wish to purchase an eprom eraser or a sophisticated eprom programmer. In addition to not requiring total erasure, the devices can be programmed by very simple and inexpensive equipment, two examples of which I shall describe to you in a moment.

The eprom devices which may be considered for substitution by eeprom or battery-backed types, and for which the two projects cater, are those of the 2048 words x 8 bits variety having the pin configuration shown in Fig.1. Such eproms include the types 2516, 2716, 27C16 etc, irrespective of their prefix and suffix letters. The equivalent eeprom devices are those of the type 2816, eg X2816AP-35. An equivalent lithium battery-backed device is the MK48T02-20. Both the latter devices are available from Electromail;

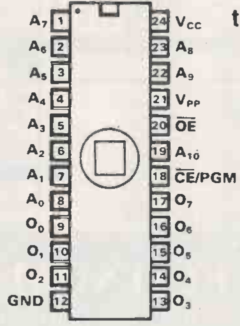


Fig 1. Pin-outs for eprom types 2516.

they are quite likely available from many PE advertisers as well, either as identical devices or as their equivalents from other manufacturers.

## KEYPAD PROMMER

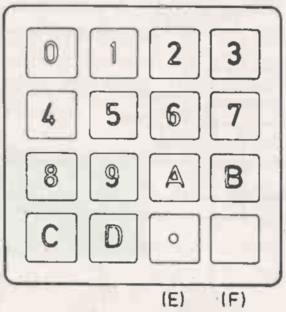
First, I shall describe a simple keyboard operated unit which includes an alpha-numeric readout display. Next month I'll describe an even simpler and cheaper unit in which the data is entered using switches and monitored on a bank of leds.

There are four requirements to be met when programming eproms, eeproms or battery-backed substitutes: selection of data code, selection of address code, activation of read-write mode, and checking of correct data acceptance.

With this month's unit, data is entered from a hexadecimal keypad. The address code can be stepped through bit by bit using a push switch, or run through constantly at a rate set by a variable speed oscillator. Data is written into the memory by pressing a push switch. The data code can be monitored both before and after it has been stored in memory, using hexadecimal led displays.

## HEX KEYPAD

I chose the cheapest keypad I could find. It had the required 16 keys, though they were numbered 0 to 9, A, B, C, D, plus a dot and a blank, and were not in the desired order (Fig.2.). It was simple matter, though, to remove the screws at the back of the unit and then rearrange the pads in the order shown in Fig.3.



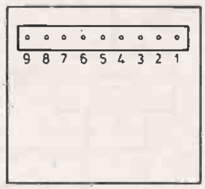
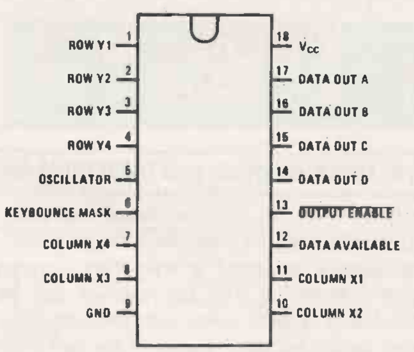


**Fig 2 (left). Keyboard before rearrangement.**
**Fig 3A (centre). After rearrangement.**
**Fig 3B (right). Rear pin connection numbering.**

The keyboard keys are electrically matrixed so that pressing a particular key couples together the designated column and line output connections. Referring to the main circuit diagram in Fig.4, the output lines are fed into the encoding chip IC1. This is specifically designed as a keyboard switch encoder ic incorporating all the logic necessary to fully encode an array of up to 16 spst normally-open switches into a natural binary code. The switch lines are sequentially scanned at a rate determined by an internal clock, the frequency of which is set by C1. The chip automatically debounces the switches, and produces an output pulse (flag) indicating that the encoded data is available at the binary outputs. The data available output goes high when a keyboard entry is made and returns low when the key is released, even if another key is depressed. The flag returns high to indicate acceptance of the new key entry after the debounce period. Internal latches store the last entry made even after the key is released. Although it doesn't concern us in this application, the chip's outputs are tri-state, allowing expansion and bus orientated operation. IC1's pin configuration is shown in Fig.5, and its internal block diagram and truth table are given in Fig.6.

You will have noticed that the program listing given for most eprom controlled projects is shown as groups of 2-character codes. Each character of the code is the hexadecimal equivalent of the decimal

**Fig 5. MM74C 922 pin-outs.**



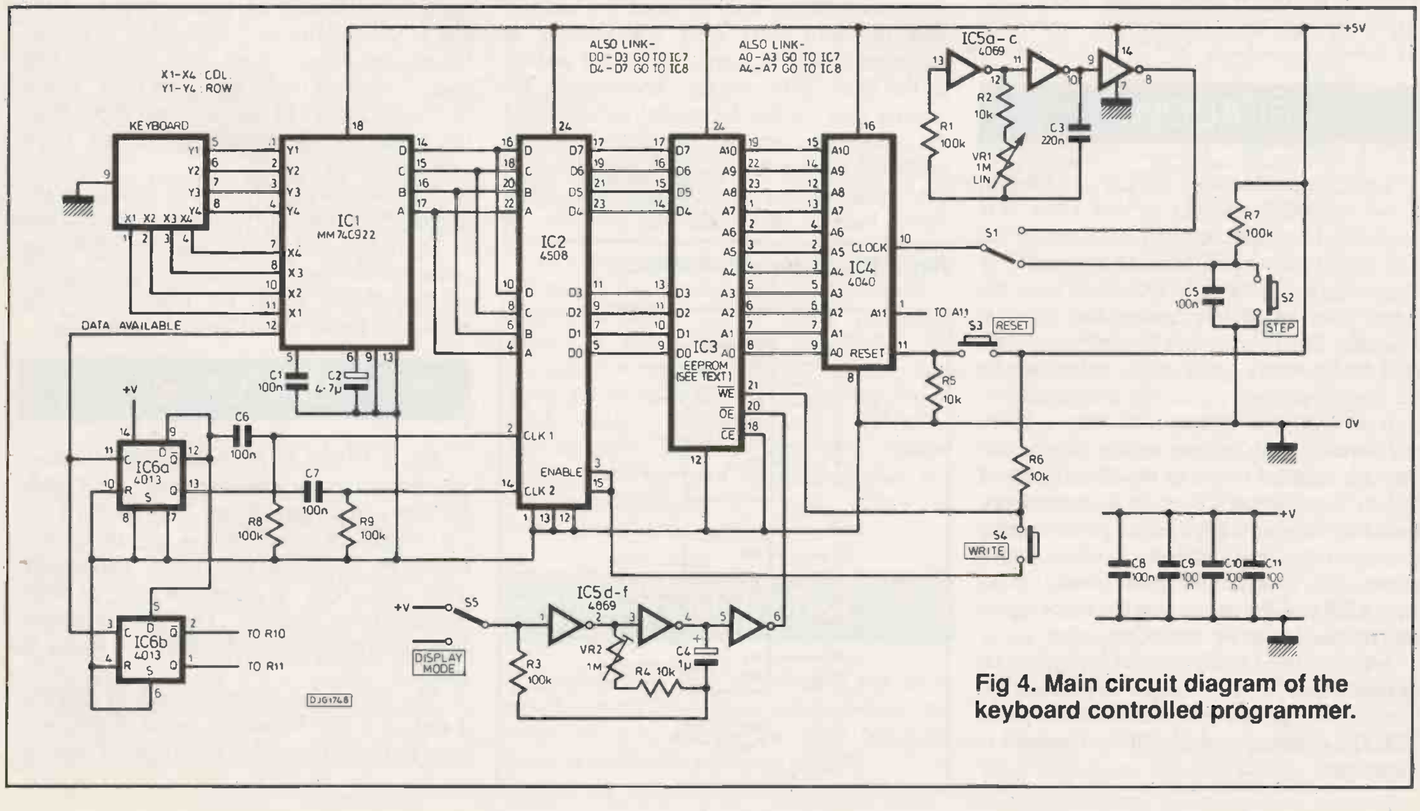
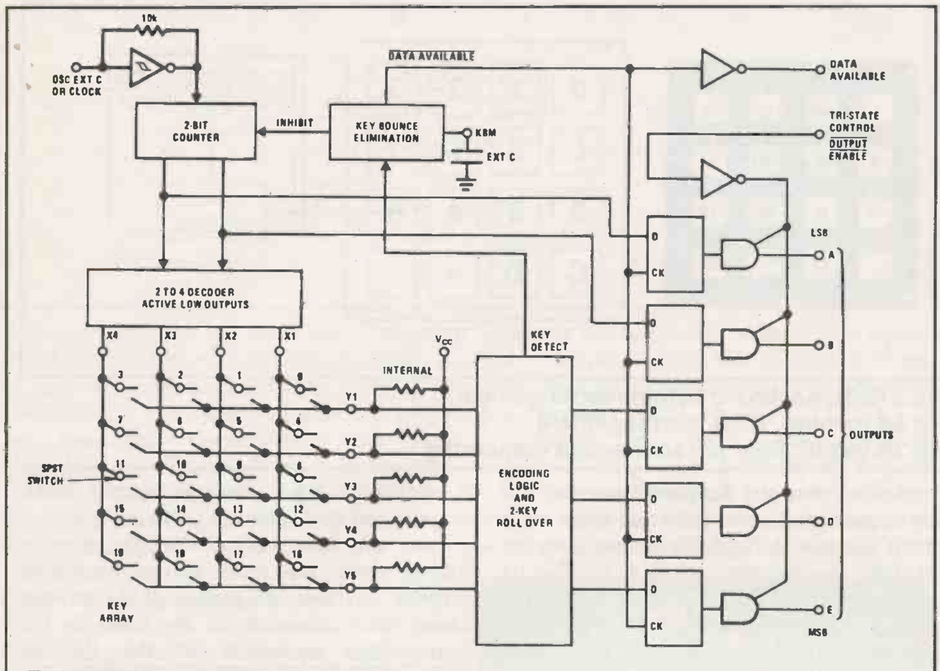


**Fig 4. Main circuit diagram of the keyboard controlled programmer.**



**Truth Table**

| Switch Position | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Y1,X1 | Y1,X2 | Y1,X3 | Y1,X4 | Y2,X1 | Y2,X2 | Y2,X3 | Y2,X4 | Y3,X1 | Y3,X2 | Y3,X3 | Y3,X4 | Y4,X1 | Y4,X2 | Y4,X3 | Y4,X4 | Y5*,X1 | Y5*,X2 | Y5*,X3 | Y5*,X4 |
| DATA OUT | A | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| | B | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| | C | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | E* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

Fig 6. Block diagram and truth table for the MM74C922.

numbers 0 to 15. The keyboard can only produce the code for one character at a time, consequently we need a temporary storage device into which two key presses can be entered. IC2 is used as the data store and is a tristate dual 4-bit latch. Either of the two 4-bit sections may be selected for data input by selection of the relevant clock input. The chip's pin-out block diagram is shown in Fig.7.

## READOUT

Since we need to store the keyboard output as two consecutive blocks each of 4 bits, it is necessary to toggle between each section of IC2. This is readily accomplished by triggering a flip flop, IC6A, each time the output flag of IC1 indicates that data is available. The flip flop is effectively a divide-by-2 device with a given output going high on the first input clock pulse, low on the second, high on third, etc. The chip has two outputs, one inverted with respect to the other. Each output is coupled to one of the clock inputs of IC2 by a capacitor, C6 and C7 respectively. Each time an output goes high a positive pulse is sent to the respective clock input, which causes IC2 to store the data present at its inputs. R8 and R9 ensure that the clock inputs are returned low at the end of the pulse.

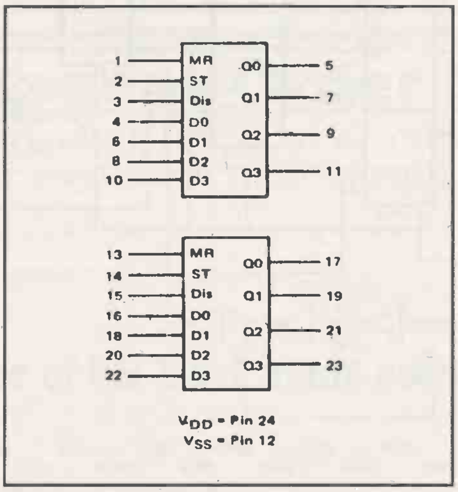
When enabled by the correct logic state on its pins 3 and 15, IC2's eight outputs are fed to the data input-output lines of the eeprom, IC3. The enabling control will be discussed in a moment.

## ADDRESS COUNTING

The address to which the keyboard data will be written in the eeprom is determined by the counter IC4. This is a 12-bit binary divider of which only 11 outputs are used for addressing. S3 is used to reset the counter back to zero, and then the address is incremented step by step using S2, R7 and C5 as the clock pulse trigger. Additionally, the counter may be fast-forwarded by switching the clock input, via S1, to the variable rate oscillator around IC5a-c. This allows you to quickly run up to a particular address and then switch back to step mode. The frequency of the oscillator is basically set by C3, and is variable by setting the panel control VR1.

When both 4-bit blocks of keyboard data are stored in IC2, the resulting 8-bit code is written into IC3 by pressing S4, so taking the write-enable input, pin 21, to ground. When S4 is released, pin 21 is returned high via R6, so putting IC3 back into read mode.

Fig 7. Block diagram for 4508.



## ENABLING

The eeprom, of course, has common input-output lines and it is necessary to avoid the conflict of both IC2 and IC3 being in an active output state simultaneously. This is achieved here by using another oscillator to alternately switch the output enable inputs of IC2 and IC3 between open and closed. The oscillator is formed around IC5d-e and clocks at a rate set by C4 and the total resistance of R4 and VR2. IC5f inverts the output of IC5e and the two outputs respectively control the desired enable lines.

## READOUT

Once the eeprom is programmed we shall probably want to recheck its contents by stepping or running through the address sequence. In this instance we need to hold IC3 outputs open and those of IC2 closed. To do this, S5 is switched so that the enabling oscillator is halted with its outputs in the correct logic state.

Visual readout is required for both the address code and the data code. In the interests of economy, both in terms of cost and power consumption, I chose to use just three displays, two of them doubling up for both modes, Fig 8 shows the circuit.

Digits 1 and 2 are driven via two multiplexed dual 4-bit data selectors, ICs 7 and 8. One half of each chip takes in four of the address output binary lines, the other half takes in the four of the data code lines. Which of the two groups of four is output depends on the status of the control input, pin 1, as selected by S6.

The outputs of IC7 and IC8 then go to the display ICs 9 and 10, representing digits 1 and 2. Digit 3 is fed direct from the final four address code lines. Although IC3 only uses 11 of the address lines, the displays actually reflect the status of all 12 outputs from IC4.

## DISPLAYS

ICs 9, 10 and 11 are hexadecimal displays which incorporate a ttl compatible 4-bit latch, decoder and display driver. They have a 4 x 7 led dot format which allows any of the hex characters, 0-9 and A-F to be configured. They also have a choice of left or right decimal point displays. The pin connection data and internal block diagrams are shown in Fig.9.

The right hand decimal points of displays 1 and 2 are used to indicate which display will receive the next number programmed into the

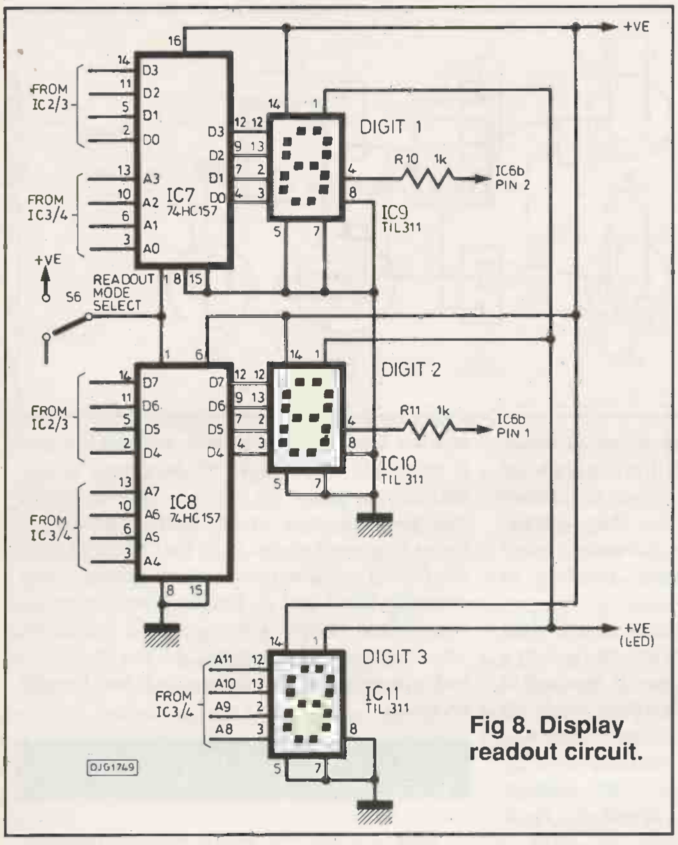


**Fig 8. Display readout circuit.**

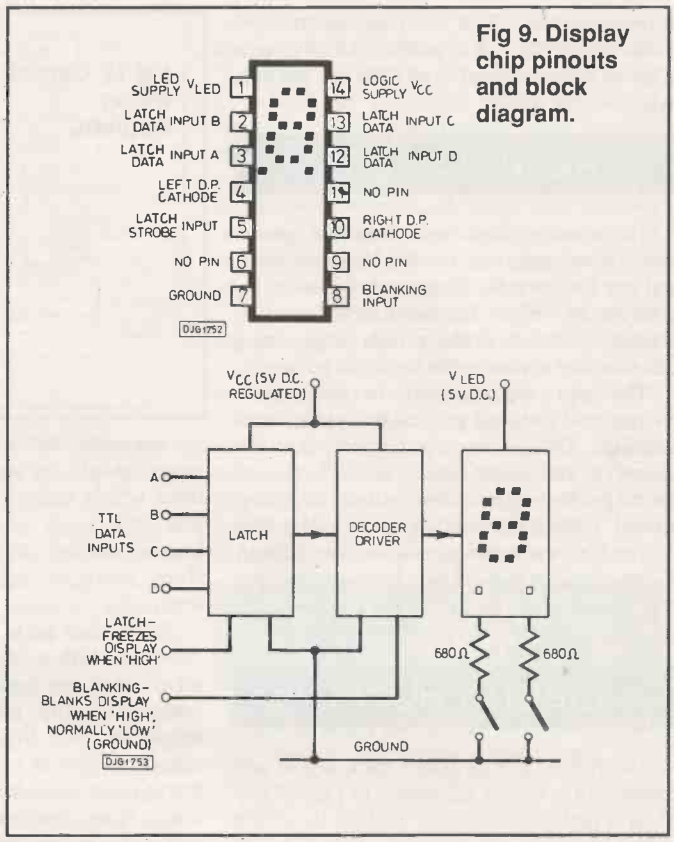
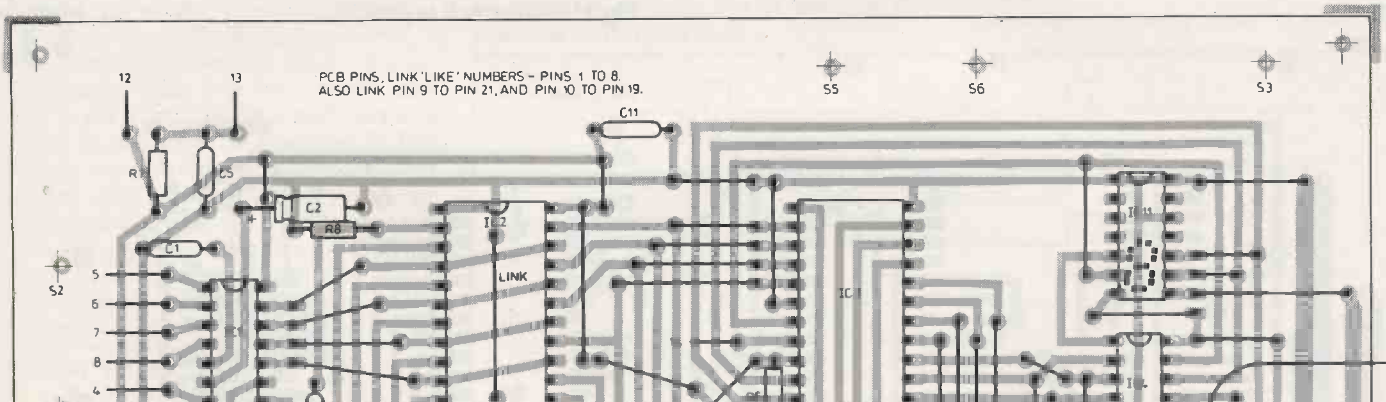


**Fig 9. Display chip pinouts and block diagram.**

**Fig 10. PCB components layout.**



keyboard latch. The decimal points are controlled by the flip flop IC6b, which in turn is set by the not-Q output of IC6a and the data available flag of IC1.

## POWER NEEDS

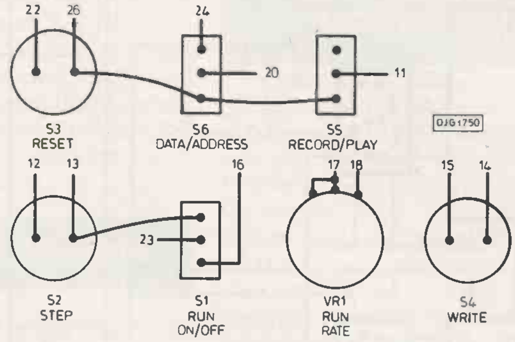
The display chips have two +5V power line connections, one for the logic circuitry, and one for the leds. On the pcb I allowed for separate +5V lines for the functions but in practice I found no problem with simply using one +5V line connected to both pcb points.

The power requirement is obviously for a 5V psu, and it should preferably be fairly well stabilised. Do not use a psu greater than 5V otherwise you could rapidly kill off most of the chips. Power consumption is quite heavy, around 150mA for the logic, including that required by the eeprom, and another 150mA for the displays with all leds lit. A suitable psu was described in the Easibuild circuit of PE July 89.

## CIRCUIT BOARD

The printed circuit board track layout and component positions are shown in Figs.10 and 11. It is preferable to use ic sockets for all the chips, including the displays. For IC3, the eeprom position, it is recommended, though not essential, that a zif (zero insertion force) socket should be used. ZIFs have a lever on them which enables you to open the socket pins and easily push in the chip without excess pressure; an obvious advantage when chips need to be frequently inserted or removed.

**Fig 12. Control wiring diagram.**



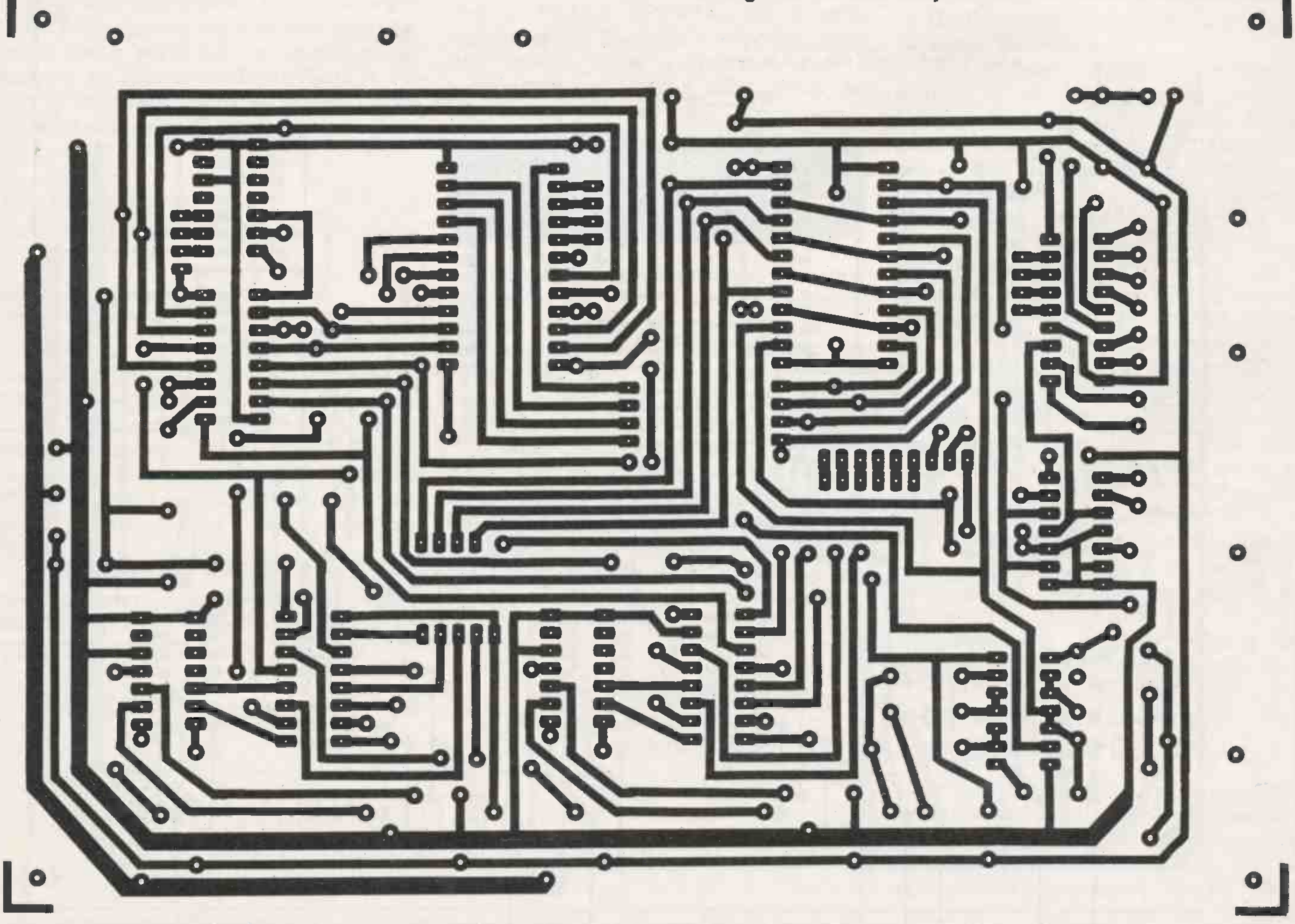
Rather than go to the expense of a double-sided pcb, I have used link wires to connect a lot of the points together. There is no need to laboriously strip plastic sheathed wires to length for each link, just a single uncoated strand of wire is all that's needed, ensuring that it's taut enough not to touch any adjacent links. Note that one link should be made before IC2 is inserted.

For my own model I mounted the switches and not directly onto the pcb, and did not feel it necessary to put the unit in a box; wiring details are shown in Fig.12. The keyboard was also mounted on the board, inserting it into a 9-way sil socket (one half of an 18-way dil socket trimmed with wire cutters), and covering ICs 1 and 2. The keyboard numerals should face you from the righthand side of the pcb. You could alternatively put the unit into a box, mounting the switches, pot and keypad on its lid.

## TESTING

First test out the board without inserting the eeprom, but with all other ics in place. Set

**Fig 11. PCB track layout.**



VR1 and VR2 to maximum resistance (slowest oscillator rates) and S5 to pre-view mode. Then, if you have a voltmeter, check that the outputs of the two oscillators toggle up and down. Switch S1 to constant run mode, and S6 to address display mode. Check that the led displays count upwards through their full cycle of hex digits and that pressing S3 resets the counter to zero. Switch S1 to step mode and check that S2 steps the counter through correctly.

## KEYBOARD PROGRAMMER COMPONENTS

**RESISTORS**

R1, R3, R7-R9 100k (5 off)
R2, R4-R6 10k (4 off)
R10, R11 1k (2 off)
All 0.25W 5% carbon film

**CAPACITORS**

C1, C5-C11 100n polyester (8 off)
C2 4µ7 16V elect
C3 220n polyester
C4 1µ 16V elect

**SEMICONDUCTORS**

IC1 74C922
IC2 4508
IC3 see text
IC4 4040
IC5 4069
IC6 4013
IC7,
IC8 74HC157 (2 off)
IC9-IC11 TIL311 (3 off)

**POTENTIOMETERS**

VR1 1M lin rotary
VR2 1M skeleton preset

**SWITCHES**

S1, S5, S6 min spco toggle (3 off)
S2-S4 min push-make (3 off)
Keyboard 4 x 4 alphanumeric keypad (see text)

**MISCELLANEOUS**

8-pin dil sockets (8 off), 18-pin dil sockets (2 off), 24-pin dil sockets (2 off), knob, printed circuit board.

Switch S6 to keypad data mode and check that pressing the keys results in the correct number being displayed on one or other of the first two digit read outs, and that the keypad interpretation circuitry switches alternately between the digits each time a key is pressed. Also observe that the decimal point displays alternate for each key press.

If in the process of checking-out anything misbehaves switch off and recheck your joins and that no shorts exist between tracks (you should, of course, have done this anyway before switching on!). It's likely that any malfunction will be due to incorrect assembly in some way rather than to chip failure, which is extremely rare nowadays (though not impossible).

## PROGRAMMING

Once satisfied, switch off, insert an eeprom and switch on again. Switch S1 to step mode and press S3 to reset the counter. You are likely to see the data readout displays alternating between two numbers, probably FF from the eeprom and whatever codes are stored in IC2. Press two keys on the key pad and observe the numbers displayed (still alternating with the eeprom output code). The rate at which the codes alternate can be varied by adjustment of VR2.

Press the write switch, S4, and release it. The code entered from the keypad should now appear static, indicating that the eeprom has accepted it. Press the step switch S2 once, so incrementing the address counter by one. Again you should see two codes alternating, the code last entered into the keypad, plus the code in the eeprom for the new address, again probably FF. Enter a new two digit code, note it and press the write switch to enter it into the eeprom. Repeat several more times, incrementing the counter each time. As a check that the counter is being correctly incremented it is advisable to briefly switch the displays to address mode each time the step switch is pressed. If in some way, the address is incorrect, or later you discover that you entered the wrong code, you can reset the counter to zero, and either run or step it through to the correct address and reenter the code.

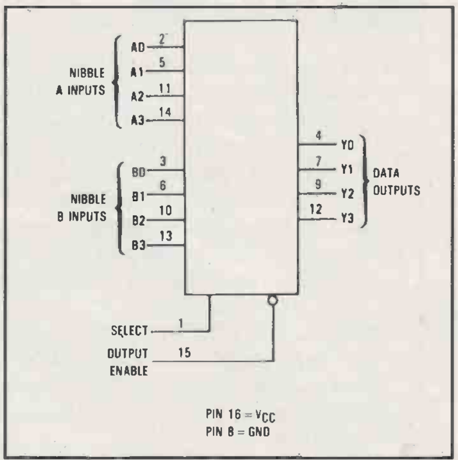


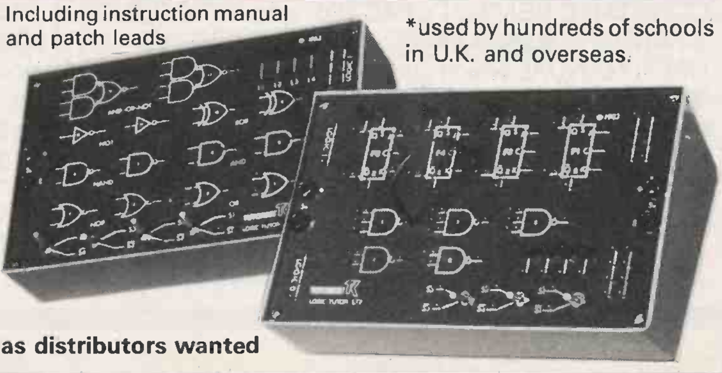
Fig 13. Block function diagram for the 74HC157 chip.

When you've programmed in as much code as you want, switch S5 to post-view mode (so stopping the enabling clock and ensuring that only the eeprom outputs are routed to the displays). Reset the counter to zero, then step it through observing that at each step you see the same code on the displays that you had previously noted. Assuming success on this checking, you've built yourself a working eeprom programmer! You can now get on with building and operating an eprom or eeprom controlled microprocessor project ...

**Those who are wanting to build the even simpler eeprom programmer are invited to join us again next month. In the same issue we shall also show how either of the two programmers can be converted for programming standard eproms of up to 4096 words by 8 bits. So, program yourself not to miss Part Two!** PE

## EASI-BUILD PROJECT

**So sorry but we have not had the space to bring you an Easi-Build project in this issue. We hope to offer you another one next month.**



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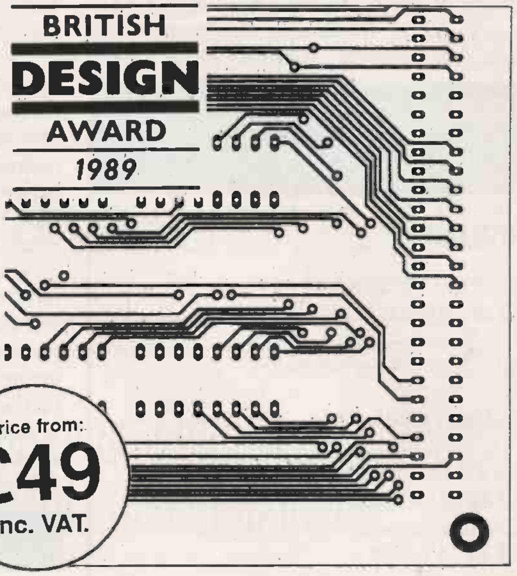

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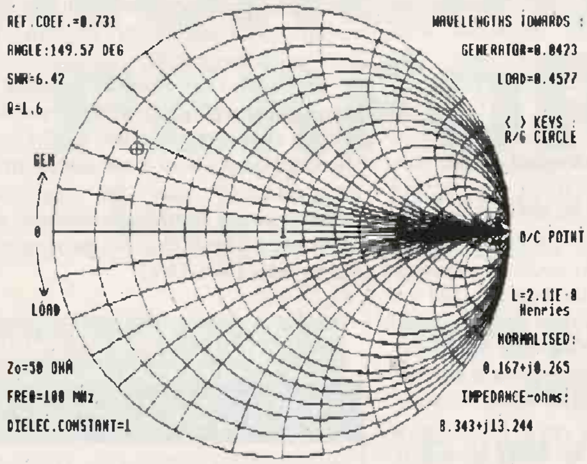

```
REF.COEF.=0.731                 WAVELENGTHS TOWARDS :
ANGLE:149.57 DEG                    GENERATOR=0.0423
SWR=6.42                                 LOAD=0.4577
Q=1.6
                                          < > KEYS :
                                          R/G CIRCLE
GEN

0                                        O/C POINT

LOAD                                     L=2.11E-8
                                         Henries
                                        NORMALISED:
Zo=50 OHM                               0.167+j0.265
FREQ=100 MHz                         IMPEDANCE-ohms:
DIELEC.CONSTANT=1                     8.343+j13.244
```

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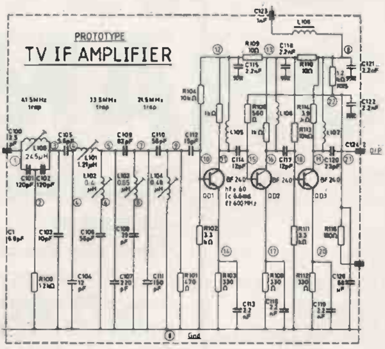

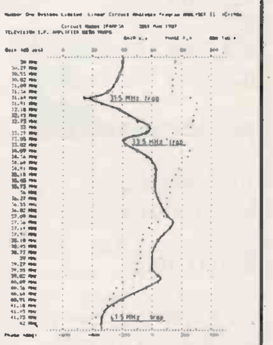

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# BASIC ELECTRONICS

## PART ONE – ELECTRICITY

### Volts and currents explained and illustrated: the beginner's guide to universal electronics!

This series aims to introduce you to electronics from the very beginning. Electronics is about devices that work by using electric currents. Such devices include radio sets, tape recorders, digital clocks, television sets, fax machines, automatic cameras, cash registers, tv sets, video recorders, electronically controlled washing machines, security systems, robot arms, pocket calculators, computers and a host of other electronic machines that we meet every day at home, in the office, in the shops, in the factory, and at school. Life nowadays would be very different if it were not for electronics. Since the working of all electronic devices depends on electric currents, we shall have to start this series by talking about electricity. What is it and what are its properties?

With any machine of any kind, from a corkscrew to a computer, nothing happens without a supply of energy. Converting energy from one form to another is what machines - including electronic machines - are all about.

There are many forms of energy, including light, the energy of a moving object (kinetic energy), thermal energy (heat), chemical energy and electrical energy. What is special about electrical energy is that it is the result of *electrical charge*. This brings us to a basic question - what is electric charge? This question is simple to ask but very hard to answer. Probably no-one knows exactly what electric charge is. The best we can say is that it is a *property of matter*, more precisely a property of the particles (such as electrons and protons) from which atoms are made.

Although we can not say what charge *is*, we can investigate some of its properties.

***Investigation 1 -***
***Electric charges***

You need: Two strips of polythene sheet (this is the flexible, slightly cloudy plastic used for making sandwich bags).

Two strips of cellulose acetate sheet (this is the rather stiffer, clear plastic used for packaging items such as shirts).

A piece of woollen cloth.

Everything used must be *dry*.

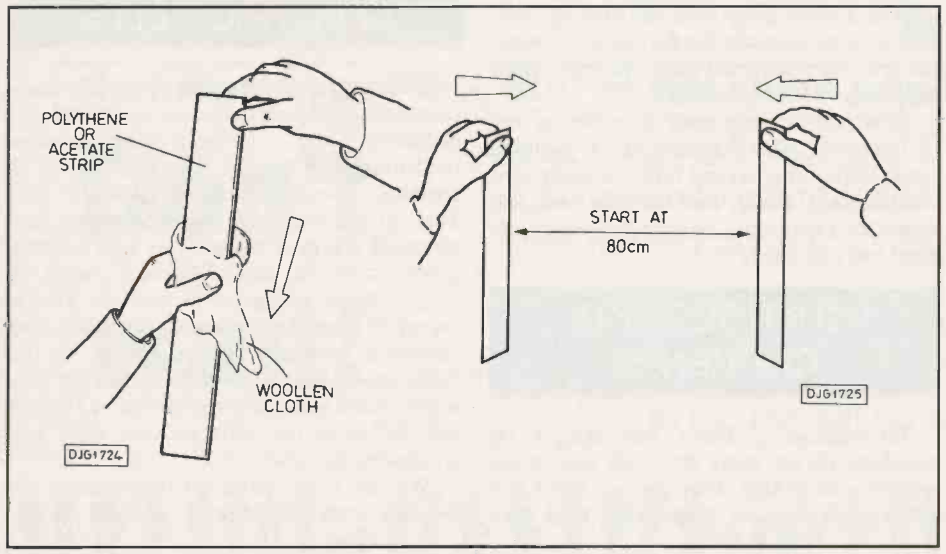
Take one of the polythene strips, wrap the cloth around it, and pull the strip through the cloth three or four times (Fig. 1) to charge it. Lay it on the table while you charge the other strip in the same way. Then hold one strip in each hand (Fig. 2) about 80 cm apart, so that they both hang vertically. Slowly move your hands together, watching what happens to the strips.

Repeat this, using the two acetate strips. What happens?

Finally rub one polythene strip and leave it on the table while you rub one acetate strip. Hold a strip in each hand, and slowly bring them together. What happens?

Results are discussed later, but try to work out what they mean *before* you read the discussion.

**Fig 1 (left). Charging a plastic strip.**
**Fig 2 (right). Bringing the charged strips together.**



## ELECTRIC CHARGE

The investigation shows that there are *two sorts* of charge. Since these two sorts have an opposite effect, we call them *positive charge* and *negative charge*. These names do not mean that one kind of charge has got something that the other kind lacks - it merely means that they are opposite in nature.

The other things that the investigation shows are that:

* like charges repel each other
* unlike (opposite) charges attract each other.

In the investigation, you charged the strips by rubbing them. The rubbing did not *make* the charge. The charge was there already. The plastic had both positive and negative charges on it. In that state it was *neutral*, since the effects of the positive and negative charges cancelled each other out. Rubbing the plastic with wool takes one kind of charge on to the wool and leaves the other kind on the plastic. The rubbing provides the energy to separate the two kinds of charges. You can see that energy is essential to separate the two kinds, since naturally they are attracted to each other. Whether the negative charges remain on the plastic and the positive charges come away on the wool, or the other way round, depends on the type of plastic.

## ELECTRIC FIELDS

The way charges attract and repel can be understood by using the idea of *electric fields*. Imagine a single positive charge, all by itself in Space. The region around it is filled with an electric field (Fig. 3). What we mean by this is that any charged object in this electric field is subject to a *force*. The force gives the object the energy with which to move.

If there is a negative charge in the field of the positive charge, the field around the positive charge attracts the negative charge toward it. At the same time, the positive charge is attracted by the field around the negative charge. If both charges are free to move, they are attracted to move *toward each other*. The line in the diagram is a *line of force*, showing the path along which the charges move toward each other. If the two charges are not free in Space but happen to be attached to a polythene strip and an acetate strip, as in the investigation, the force of the electric field still attracts them to move together. In this situation the force on the charges pulls the strips together.

In the same way we can explain the effect of like charges repelling (Fig. 4).

This discussion of electric charges and fields may all sound very theoretical, and a bit remote from hi-fi amplifiers and computers.

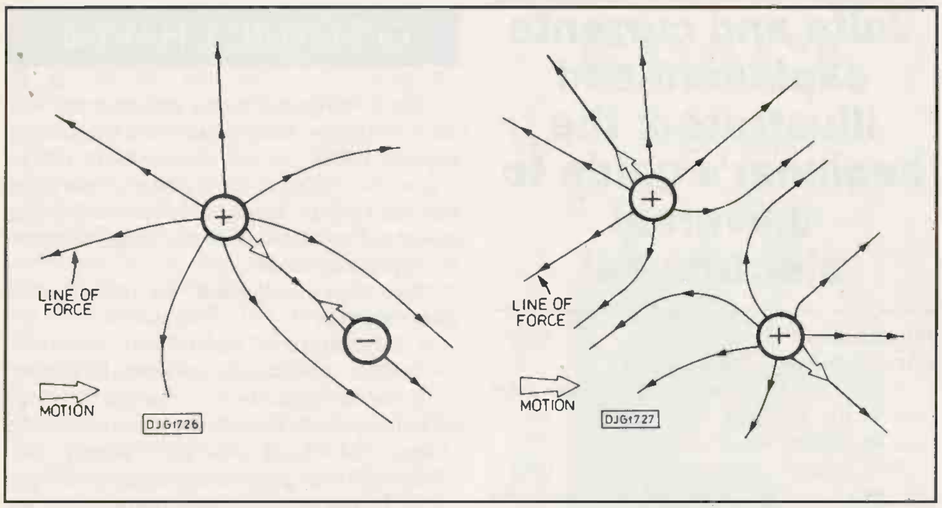


**Fig 3 (left). Field of a positive charge, with nearby negative charge attracted toward each other. Fig 4 (right). Fields of two positive charges, repelled by each other.**

These all have electric *currents* whizzing around inside them. What has this to do with charges on plastic strips? But the connection is not as remote as it seems. In fact, several of the electronic devices that we shall look at in this series depend on the properties of charges and fields, rather than on electric currents. Let us try to make the connection between charge and current.

***Investigation 2 -***
***Does charge move?***

You need: the equipment of Investigation 1.

Insulating supports, eg. large cardboard box.

Charge one of the polythene strips and attach it to an insulating support (Fig. 5). It must hang vertically. Take a new polythene strip and rub *only one end of it* so as to charge only that end. Hold it as shown so that the uncharged end is beside the hanging strip. The strips may repel each other a *little*, because it is almost impossible to avoid rubbing the strip slightly while cutting it or handling it. Now hold the strip the other way up. What do you notice?

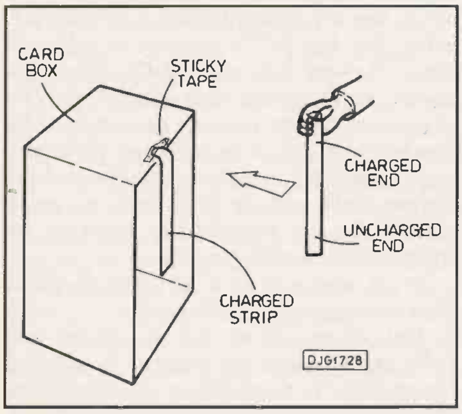
***Investigation 3 -***
***Moving charges***

You need: the equipment of Investigation 1.

A milk bottle.

A piece of ordinary single-stranded connecting wire about 75cm long, with the insulation stripped from about 5cm at each end.

**Fig 5. Does charge move?**



Charge a polythene strip and hang it vertically from a support. Now support the wire on the milk bottle with its stripped ends bent, as shown (Fig. 6). Move the near end of the wire slowly toward the hanging strip. You will probably find that the strip is slightly attracted toward the end of the wire. This is due to an effect that we will not go into here. Position the wire so that the strip *just* begins to be attracted, but does not move toward and touch the wire. Leave them for a second or two until the strip hangs vertically again.

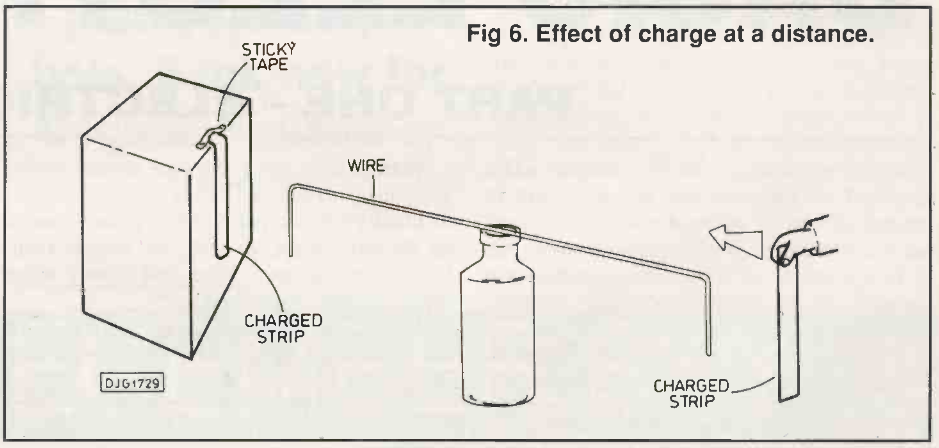


**Fig 6. Effect of charge at a distance.**

Now charge another polythene strip. Hold it about a metre away from the hanging strip. Slowly bring it toward the far end of the wire. Let it swing toward and touch the wire. What happens to the hanging strip?

Now pull the strip away from the far end of the wire. What happens to the hanging strip? Repeat this several times to make sure what happens. Finally take the wire away and repeat the experiment, holding the strip *at the same place as before*.

## CHARGES AND CURRENTS

Investigation 2 shows that charges on polythene do not move from one part of the polythene to another. They have an effect at a distance, because of the electric field they produce, but the charges themselves 'stay put', where they were first separated by rubbing. The polythene does not carry (or conduct) the charges from one part of itself to another. Other substances that have the same property are cellulose acetate, other plastics, glass, rubber, wool, cotton, and wood. These are all said to be *non-conductors*, or *insulators*.

Investigation 3 shows that charges do move about in the copper wire. The direction in which they move is decided by any electric fields that happen to be present. Other metals and also carbon can carry moving charges and, for that reason are said to be *conductors*.

The factor that decides whether a substance is a conductor or non-conductor is whether or not there is anything in the substance to conduct charge. What we need are *charge carriers*. These must be mobile within the substance, so that the charge can be carried from one place to another. Non-conductors have no mobile charge carriers. Atoms in the non-conductor may become charged when they gain or lose electrons, but the atoms remain fixed in position in the structure of the material. They cannot carry the charge about.

In metals the charge carriers are *electrons*. These electrons belong to the atoms of the metal, but they are free to move about from one atom to another. It is as if the piece of metal contained an *electron gas*. Electrons have negative charge, so a current in a metal is a flow of negative charge.

## ELECTRIC CELLS

Another way of making a current flow in a piece of wire is to connect it to an electric cell or battery. There is an electric field between the terminals of the cell. This is the result of chemical changes occurring inside the cell. The cell has converted chemical energy into electrical energy. Compare this with rubbing plastic strips, in which chemical energy in your muscles is converted into the kinetic energy of your moving hands, which is in turn converted into the electrical energy of the fields around the plastic strips. When the wire is connected between one terminal of the cell and the other the current flows from one terminal to the other.

We normally think of the current as flowing from the positive terminal to the

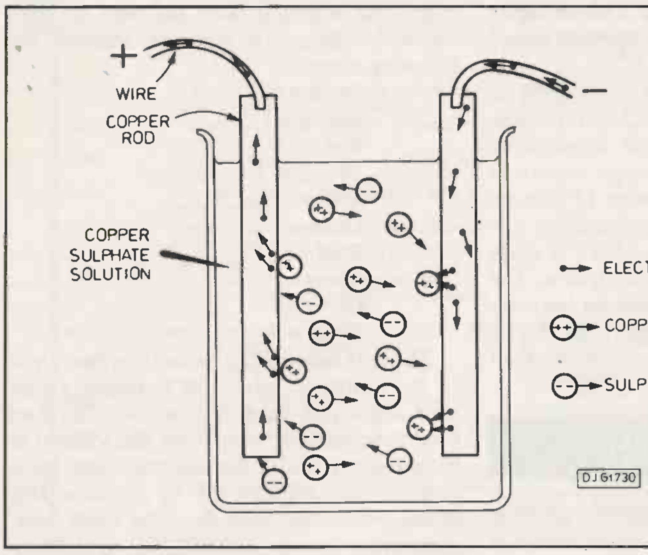


Fig 7. Flow of electric charge in a solution of copper sulphate.

negative terminal. This idea originated in the days when we did not know what an electric current is. It was simply assumed that it flowed from what scientists just happened to call the 'positive' terminal to what they happened to call the 'negative' terminal. As it turned out, this idea is wrong - though it is still a useful one and we still normally think of current in that way most of the time. But, if we really want to understand what happens in an electric circuit we must update our ideas on current. What happens when current flows in a metal (eg the wire connecting the battery terminals) is that *electrons* flow from the negative charge so they are repelled by the negative terminal of the battery and attracted by the positive terminal. The *electric field* between the terminals make them *move*.

**Electric current in a wire is a flow of negative charge carriers (electrons) from negative to positive.**

This is the way current flows in most circuits, since most circuits use metal wires or tracks as the conductors.

## OTHER KINDS OF CHARGE CARRIER

Conduction in solutions occurs because dissolved substances ionise to form positive and negative *ions*. For example, copper sulphate in solution forms copper and sulphate ions:

$CuSO_4 \rightarrow Cu^{++} + SO_4^{--}$

The copper atom has *lost* 2 electrons (2 units of negative charge), so leaving it positively charged. The sulphate ion gained these 2 extra electrons, so acquiring negative charge. If two electrodes (eg rods of copper) are placed in such a solution and a battery is connected, the ions act as charge carriers (Fig. 7). The copper ions move toward the negative electrode, since unlike charges attract. Here they gain electrons which have come from the battery through the wiring of the circuit. The copper ions are discharged and deposited on the electrode as a bright reddish layer of copper. As the amount of copper ions in the solution decreases, copper atoms of the positive electrode give up two electrons each and become copper ions:

$Cu \rightarrow Cu^{++} + 2e^-$

The positive electrode gradually loses copper. The electrons flow to he positive terminal of the battery. Thus the copper ion is a positive charge carrier. The sulphate ions are attracted to the positive electrode but they do not become discharged, so they do not act as charge carriers.

Another type of conductor is a gas at low pressure. The neon lamp, often used in electronics as a pilot lamp, is an example. Conduction is by electrons. Since neon has few free electrons to act as charge carriers, it needs a strong field to force electrons across from one plate of the lamp to the other (Fig. 8). When the pd exceeds 70V a few electrons are able to cross. As they pass they hit neon atoms and knock more electrons from them. This creates neon ions, which are positively charged, having lost an electron. There are now plenty of free electrons to act as negative charge carriers, and the neon ions act as positive charge carriers. The gas conducts freely. The energy from the moving carriers excites the neon atoms, making them glow with a reddish light.

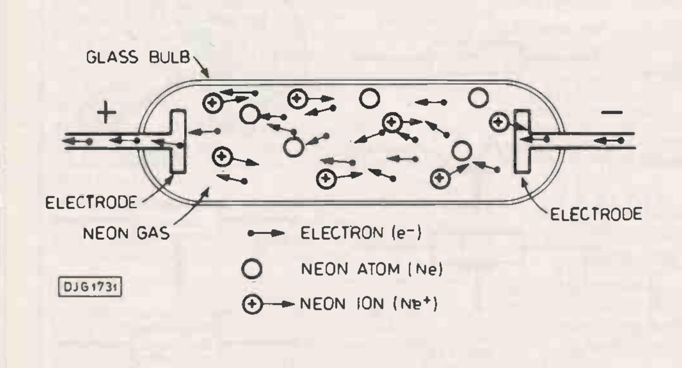


Fig 8. Flow of electric charge in a neon lamp.

In all these instances of electric currents, the essential point is that current is a *flow of electric charge*, in the form of charged particles (*charge carriers*).

## OPPOSING THE FLOW

Earlier we thought about charged particles moving in Space but, in real life (in a real piece of wire, for example), the charge carriers move through regions that already contain other particles, charged or not. They are not entirely free to move. There may be other particles such as the atoms of metal of the wire blocking their path, possibly attracting them or repelling them. It has the same effect (though it does not involve the same kinds of forces) as air resistance has on a ball when we throw it. Air resistance opposes the motion of the ball. Electrical resistance opposes the motion of the charge carriers. The harder we throw the ball, the more easily it flies through the air. Let us see if the same sort of thing applies to electrons in a wire.

***Investigation 4***
***Electrical resistance***

You need:

A battery box holding 4 cells, 1.5V each.

A testmeter or milliammeter, full scale 200mA or 500mA.

The element of a 2kW electric heater, or an electric iron.

We use this as the electrical resistance in this investigation. It is best to remove the element from the heater but you may be able to manage without doing this. If you are using an iron, you can usually connect the iron into the circuit through the two pins on its plug.

Connecting wire.

First draw out a table for your results:

| Potential difference (V volts) | Current (I amps) | V/I |
|---|---|---|
| 1.5 | | |
| 3.0 | | |
| 4.5 | | |
| 6.0 | | |

The first column of the table refers to the potential difference (or voltage) across the element. The voltage produced by each cell is 1.5V; if we have two cells joined in series we get 3V; three cells gives 4.5V and four cells gives 6V. By making the connection at the right place in the battery box you can get all four voltages listed in the table.

Connect the circuit as in Fig. 9. Touch the flying lead against the point indicated, so that the voltage across the element (and meter) is 1.5V. Measure the current. The meter is reading current in milliamps (we should really

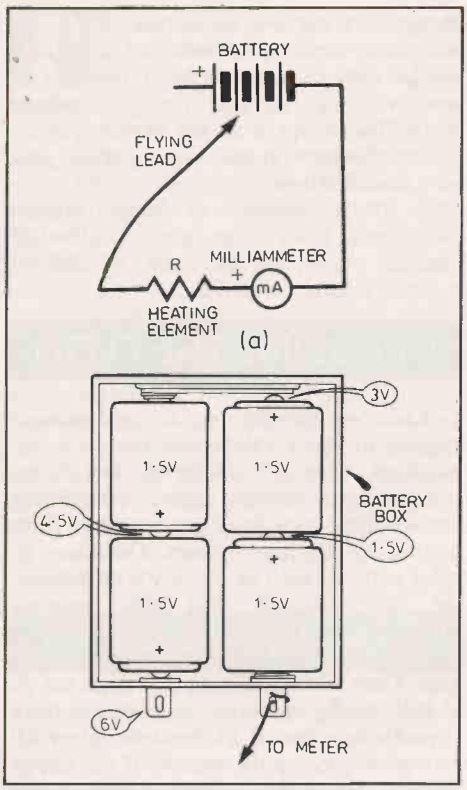


**Fig 9. Investigation 4(a) the circuit, (b) where to tap the battery box with the flying lead.**

say 'milliamperes' but no one ever does!). The table asks for the current to be written in amps (amperes!). Since an amp is a thousand milliamps, divide the meter reading by 1000. For example, if the meter reads 50mA, write '0.050' in the table; if it reads 120mA, write '0.120' in the table.

Now connect the flying lead so as to put 3V across the heater. Read and record the current again. Repeat for 4.5V and 6V.

What do you notice about your results? As the voltage increases, what happens to the current? Let us take this a bit further. The last column of the table is headed 'V/I'. Fill this in by dividing each voltage (V) by the corresponding current (I). What do you notice about the figures you have just calculated?

## RESISTANCE

The value V/I obtained in the investigation is known as the *resistance* of the element. If voltage is in volts, AND current is in amps, then the resistance is in ohms:

$R = V/I$

This equation can be re-written in other ways that mean the same thing:

$V = IR$ and $I = V/R$

The equation on the right says in symbols what can also be said in words:

*The current passing through a conductor at constant temperature is proportional to the potential difference between its ends.*

The statement above is usually referred to as *Ohm's Law*, in honour of Georg Ohm, who first investigated this subject. While we are name-dropping we should also mention Andre Ampere and Alessandro Volta, two other pioneers in the study of electricity whose names have been given to our most frequently used electrical units.

Ohm's Law specifies that the conductor must be at constant temperature. This is because electrical resistance varies with temperature. For metals, the resistance increases slightly as temperature increases. If you were to measure the resistance of the heater element when it is hot, you would find that its resistance is much less than was found in your investigation. The resistance of some other conductors decreases as temperature increases, a property that can be useful but can also be a nuisance, as we shall see later in this series.

## RESISTORS

It might be thought that electrical resistance is something to be avoided. In some branches of technology it *is*, which is why so much research is directed at finding superconductors - materials which have virtually no resistance. Once a current has been started in a superconductor it goes on flowing for a very long time. But, in electronics, resistance frequently has an essential part to play. Usually the first components on the 'Parts Required' list for a project are the resistors.

A resistor is an electronic device which has a specified resistance. Resistors are made of several different materials, the commonest being made of a carbon film on a rod of non-conducting material. Other types have a metal film or, for low-value high-current resistors, a coil of wire wound round or embedded in a ceramic material. Fig. 10 shows different types of resistors and their symbols, including variable resistors.

The value of a resistor may be marked on it in numerals but, for most fixed resistors at least, it is more usually marked by a resistor colour code. This normally takes the form of three coloured bands. The colours indicate the following numerals:

Black = 0
Brown = 1
Red = 2
Orange = 3
Yellow = 4
Green = 5
Blue = 6
Violet = 7
Grey = 8
White = 9

The first two bands give the first two digits of the resistance value. For example, a blue band and a grey band indicate '68'. The third band indicates how many times that value is to be multiplied by 10. For example, blue, grey, *brown*, means multiply '68' by ten *once*. This means '680 ohms'. On the other hand, blue, grey, yellow means multiply '68' by 10 *four times*, giving 680000 ohms, which is 6.8 megohms can be written '6M8'. What would be the colour code on such a resistor?

In the colour code, a black third band signifies 'do not multiply by 10', so blue, grey, black indicates a 68 ohm resistor. For resistors of low value we use gold and silver bands to mean 'divide by ten' and 'divide by 100' respectively. Blue, grey, gold means 6.8 ohms and blue, grey, silver means 0.68 ohms.

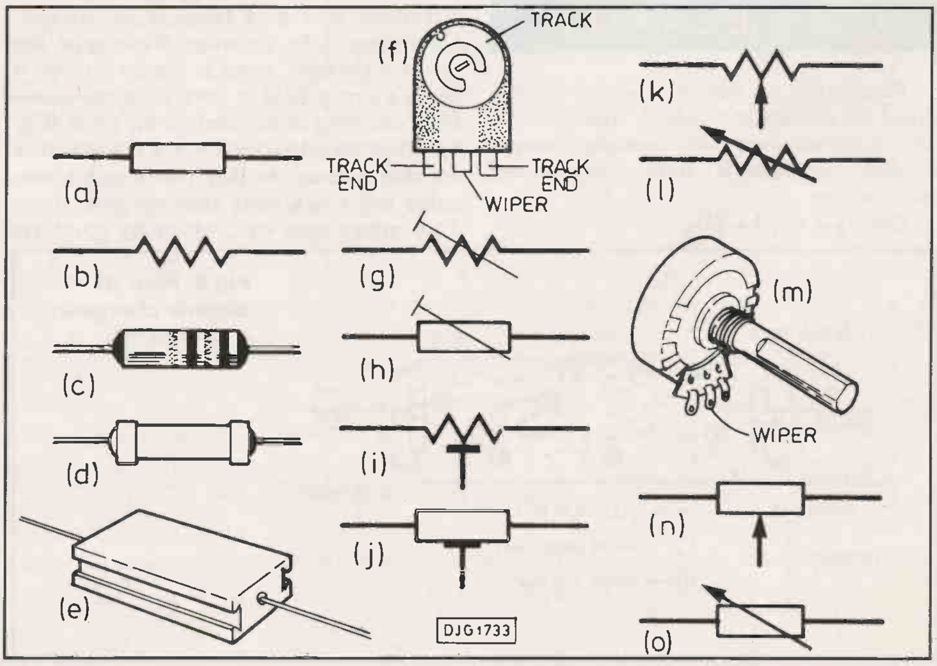
Before we go any further try to work out the resistances indicated by these colours:

(a) red, red, red
(b) yellow, violet, brown
(c) grey, red, yellow
(d) brown, black, orange

Now work out the colours corresponding to these resistances:

(e) 1M2
(f) 330 ohms
(g) 4.7 ohms
(h) 56k

**Fig 10. (a) and (b) symbols in common use for fixed resistors; (c) carbon resistor; (d) and (e) wirewound resistors; (f) preset variable resistor; (g), (h), (i) and (j) symbols in common use for (f); (m) potentiometer; (k), (l), (n) and (o) symbols in common use for (m).**



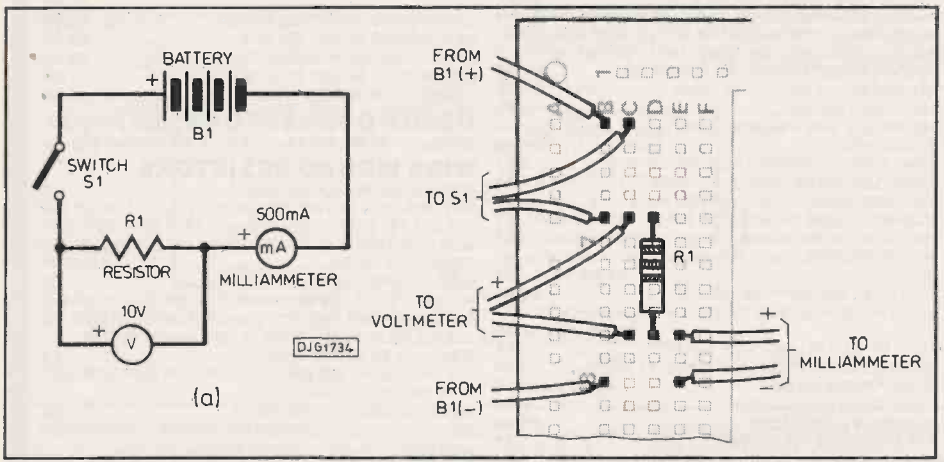


Fig 11. Investigation 5. (a) the circuit; (b) breadboard version.

Resistors are rarely made to have a precisely defined resistance. For example, when we buy a 220 ohm resistor we do not expect it to have a resistance of precisely 220 ohms. We allow the manufacturer a certain margin of *tolerance*. If a resistor has 10 per cent tolerance, its value is within 10 per cent of the value indicated by the colour code. For example, its *nominal* value is 220 ohms, but its actual value could be any value between 198 ohms (220-22) and 242 ohms (220+22). For most circuits we use resistors with 5 per cent tolerance, although 2 per cent, 1 per cent and 0.5 per cent resistors are available for more precise work - and are correspondingly more expensive. The tolerance of a resistor is indicated by yet another coloured band:

| | |
|---|---|
| 1% | brown |
| 2% | red |
| 5% | gold |
| 10% | silver |
| 20% | no band |

Since resistors have tolerance, it is pointless for manufacturers to make resistors of all possible values. The most commonly made values are known as the E12 series. This has 12 basic values:

1.0 1.2 1.5 1.8 2.2 2.7 3.3 3.9 4.7 5.6 6.8 8.2

Ten-times multiples of each of these are also made, for example:

27 270 2k7 27k 270k 2M7

These values are all sufficient for most purposes since, with 10 per cent tolerance, the ranges of next-door resistors in the series all overlap. For greater accuracy with 5 per cent tolerance there is the E24 series which includes 'in-between' values such as:

1.1 1.3 1.6 2.0 etc.

Now we will check up on the manufacturers by measuring the actual values of some resistors.

***Investigation 5***
***Measuring resistance***

You need:

a battery holder with four 1.5V cells (total 6V);

a switch;

a testmeter or milliammeter reading up to 500mA;

a testmeter or voltmeter reading up to 10V (not essential, see below);

several resistors with resistance less than 1 kilohm;

a breadboard (optional).

Connect the circuit of Fig. 11, using one of the resistors.

Switch on. Measure (a) the voltage across the resistor (should be fairly close to 6V); and (b) the current flowing through the resistor. If you have only one testmeter, use this to measure current and assume that the voltage across the resistor is 6V.

Calculate the resistance, using the equation we explained above: R=V/I. Remember I must be in *amps*, not *milliamps* for this calculation. How close is the actual resistance to the nominal resistance as shown by the colour code? Is this within the tolerance limits?

Repeat this for a few other resistors.

## MEASURING HIGH RESISTANCE

The technique of Investigation 5 is not suitable for measuring resistances higher than about 1 kilohm. This is because the voltmeter requires current to make it work. The ammeter shows the current flowing through the resistance *and* the current flowing through the voltmeter. The current flowing through the voltmeter is very small, usually less than a milliamp. When measuring a low resistance, the amount of current flowing through the resistance is relatively large. The small extra current flowing through the voltmeter makes little difference to the result. But if we are to measure a high resistance, a very small current passes through it. The current through the voltmeter may be almost as much or possibly more than this. The result is far from correct.

Fig. 12. Circuit for measuring high resistance.

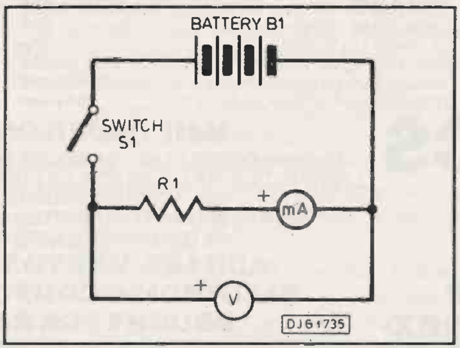


Fig. 12 shows how to rearrange the circuit for measuring high resistances. Now the ammeter measures only the current going through the resistor and not the current going through the voltmeter. You might ask 'Why did we not use this more precise circuit for Investigation 5?' The answer is that Fig. 12 is not suitable for measuring *low* resistances. We will explain why later.

## RESULTS AND ANSWERS

***Investigation 1***: When you move the polythene strips together their free ends repel each other. This is because they have been *charged*. Some of the energy you put into rubbing has appeared as electrical energy. It forces the ends of the strips apart.

The same thing happens with the two acetate strips. With one acetate strip and one polythene strip, the free ends of the strips move together. They *attract* each other.

Charged polythene is repelled by charged polythene, but attracted by charged acetate. The kind of charge on polythene must be different from the kind of charge on acetate. They have opposite effects.

***Investigation 2***: The effect of charging is restricted to the region of the strip that was rubbed. The charge can not move from one part of the strip to another part.

***Investigation 3:*** When the wire is taken away there is no effect. The effect of the charged strip must have been transmitted along the wire. This is explained by supposing that the wire contains electrons that are free to move. The polythene strip is negatively charged - its surface has many electrons on it. When the polythene strip is brought toward the right-hand end of the wire, the electrons on the strip repel the electrons in the wire. They move along to the left-hand end of the wire and become concentrated there. The increase in negative charge at that end repels the hanging polythene strip which is also negatively charge. For this effect to have happened the electrons must have moved along the wire - there was an *electric current* in the wire. The reverse effect occurs when the strip is moved away.

***Investigation 4***: As the voltage increases, the current increases. V/I is about the same for all 4 voltages tested.

***Colour Codes***: 6M8 is blue, grey, green.
(a) 2k2
(b) 470 ohms
(c) 820k
(d) 10k
(e) brown, red, green
(f) orange, orange, brown
(g) yellow, violet, gold
(h) green, blue, orange

**There will be more on resistors and potential dividers next month.**

## ELMASET INSTRUMENT CASE

| | |
|---|---|
| 300 x 133 x 217mm deep | **£10 ea (£2.20)** |

## REGULATORS

| | |
|---|---|
| LM317T PLASTIC T0220 variable | **£1** |
| LM317 METAL | **£2.20** |
| 7812 METAL 12V 1A | **£1** |
| 7805/12/15/24V plastic | **35p** 100+**20p** 1000+ **15p** |
| 7905/12/15/24 plastic | **35p** 100+**20p** 1000+ **15p** |
| CA3085 T099 variable reg | 2/**£1** |
| LM338 5A VARIABLE | **£5** |

## COMPUTER ICS

BBC MICRO PARTS

| | |
|---|---|
| VIDEO ULA 201647 | **£10ea** 10+ **£8** |
| 6845 CRT | **£5** |
| 6522 PIA | **£3** |
| DM88LS120 | **£4.50** |
| AY310150 UART | **£2.50** |
| IM6402 UART | **£3** |
| 8086 processor equipment | **£2** |
| USED 41256-15 | **£3.00** |
| USED 4164-15 ex-equipment | **£1** |
| 9 x 41256-15 SIMM MODULE NEW | **£25** |
| 8 x 4164 SIP MODULE NEW | **£8** |
| HD 146818 CLOCK IC | **£2** |
| 2864 EEPROM | **£3** |
| 27128A 250nS EPROM USED | **£2** NEW **£2.30** |
| FLOPPY DISC CONTROLLER CHIPS 1771 | **£10 ea** |
| FLOPPY DISC CONTROLLER CHIPS 1772 | **£16 ea** |
| 68000-8 PROCESSOR NEW | **£5** |
| HD63484-8 | **£5** |

ALL USED EPROMS ERASED AND BLANK CHECKED CAN BE PROGRAMMED IF DESIRED.

| | |
|---|---|
| 2716-45 USED | **£2** 100/**£1** |
| 2732-45 USED | **£2** 100/**£1** |
| 2764-30 USED | **£2** 100/**£1.60** |
| 27C256-30 USED | **£2** |
| 27C512 USED | **£3.50** |
| 1702 EPROM EX EQPT | **£5** |
| 2114 EX EQPR **60p** 4116 EX EQPT | **70p** |
| 6264-15 8k static ram | **£3.50** |
| 4416 RAM | **£3.50** |
| USED 4416-15 RAM | **£2** |
| USED 41464-15 | **£7** |

## CRYSTAL OSCILLATOR

| | |
|---|---|
| 1.8342 MHz | **£1 each** |

## CRYSTALS

2.77 MHz/4.000 MHz/4.9152MHz 20MHz 49.504 MHz

## TRANSISTORS

| | |
|---|---|
| BC107, BCY70 PREFORMED LEADS full spec | **£1 £4**/100 **£30**/1000 |
| BC557, BC548B | 30/**£1 £3.50**100 |

## POWER TRANSISTORS

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|---|---|
| OC35 (Marked CV7084) | **£1** |
| POWER FET IRF9531 8A 60V | 2/**£1** |
| 2SC1520 sim BF259 | 3/**£1** 100/**£22** |
| TIP141/2 £1 ea TIP112/125/42B | 2/**£1** |
| TIP35B TIP35C | **£1.50** |
| SE9301 100V 10A DARL. SIM TIP121 | 2/**£1** |
| 2N3055 EX EQPT TESTED | 4/**£1** |
| PLASTIC 3055 OR 2955 equiv 50p | 100/**£35** |
| 2N3773 NPN 25A 160V £1.80 | 10/**£16** |

## QUARTZ HALOGEN LAMPS

| | |
|---|---|
| A1/216 24V 150 WATTS | **£2.25** |
| H1 12V 50W (CAR SPOT) | **£1.50** |

| | |
|---|---|
| **14 WAY AMP ZIF SOCKET** | **2/£1** |

**TEXTOOL single in line 32 way. Can be ganged (coupling supplied) for use with any dual in line devices.**

| | |
|---|---|
| 28 WAY TEXTOOL ZIF SOCKET EX NEW EQUIPMENT | **£2** |

## CAPACITORS COMPUTER GRADE

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|---|---|
| 3300uF 350V SIC SAFCO FELSIC 037 | **£6(£1.50)** |
| 2200uF 160V SIC SAFCO FELSIC CO38 | **£4(£1.20)** |

## TURNS COUNTING DIALS all for 0.25" shaft

| | |
|---|---|
| 10 turn dial 21 mm dia. fits 3mm spindle | **£2** |
| 10 turn digital dial (3 digits) for 3mm or 6mm shaft | **£3.50** |
| 10 turn clock face dial for 6mm spindle | **£4** |

## MISCELLANEOUS

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|---|---|
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| **SLOPING FRONT PLASTIC CASE 225 x 215 x 76mm** 76 mm WITH ALI FRONT PANEL 200 x 130mm | **£4.00(£1)** |
| HUMIDITY SWITCH ADJUSTABLE | **£2** |
| WIRE ENDED FUSES 0.25A | 30/**£1** |
| **NEW ULTRASONIC TRANSDUCERS 40kHz** | **£2**/pair |
| **12 CORE CABLE 7/0.2mm OVERALL SCREEN** | **£1**/3 metres |
| **POWERFUL SMALL CYLINDRICAL MAGNETS** | 3/**£1** |
| OP AMP LM10CLN | **£2.90** |
| **BNC 50 OHM SCREENED CHASSIS SOCKET** | **3/£1** |
| **BNC TO CROC CLIPS LEAD 1 metre** | **£1** |
| **MOULDED INDUCTOR 470μH size of a 1 watt film resistor** | **5/£1** |

| | |
|---|---|
| TO-220 HEAT SINK sim RS 403-162 | 10/**£2.50** |
| SMALL MICROWAVE DIODES AEI DC1028A | 2/**£1** |
| D.I.L. SWITCHES 10 **WAY £1** 8 WAY **80p** 4/5/6 WAY | **50p** |
| 180 volt 1 watt ZENERS also 12v & 75v | 20/**£1** |
| PLASTIC EQUIPMENT CASE 9 x 6 x 1.25 in. WITH FRONT AND REAR PANELS CONTAINING PCB WITH EPROM 2764-30 AND ICS 7417 LS30 LS32 LS74 LS367 LM311 7805 REG, 9 WAY D PLUG, PUSH BUTTON SWITCH, DIN SOCKET | **£1.90** |
| VN10LM 60v ½A 5ohm TO-92 mosfet | 4/**£1** 100/**£20** |
| MIN GLASS NEONS | 10/**£1** |
| RELAY 5v 2 pole changeover looks like RS 355-741 marked STC 47WB05T | **£1 ea** |
| MINIATURE CO-AX FREE PLUG RS 456-071 | 2/**£1** |
| MINIATURE CO-AX FREE SKT. RS 456-273 | 2/**£1.50** |
| DIL REED RELAY 2 POLE n/o CONTACTS | **£1** |
| PCB WITH 2N2646 UNIJUNCTION with 12v 4 POLE RELAY | **£1** |
| 400m 0.5w thick film resistors (yes four hundred megohms) | 4/**£1** |
| STRAIN GAUGES 40 ohm Foil type polyester backed balco grid alloy | **£1.50 ea** 10+ **£1** |
| ELECTRET MICROPHONE INSERT | **£0.90** |
| Linear Hall effect IC Micro Switch no 613 SS4 sim RS 304-267 | **£2.50** 100+ **£1.50** |
| HALL EFFECT IC UGS3040 + MAGNET | **£1** |
| OSCILLOSCOPE PROBE SWITCHED X1 X10 | **£10** |
| CHEAP PHONO PLUGS | 100/**£2** 1000/**£18** |
| 1 pole 12 way rotary switch | 4/**£1** |
| AUDIO ICS LM380 LM386 | **£1 ea** |
| 555 TIMER 5/**£1** 741 OP AMP | 5/**£1** |
| ZN414 AM RADIO CHIP | **80p** |
| COAX PLUGS nice ones | 4/**£1** |
| COAX BACK TO BACK JOINERS | 3/**£1** |
| 4 x 4 MEMBRANE KEYBOARD | **£1.50** |
| 15.000uF 40V | **£2.50 (£1.25)** |
| INDUCTOR 20uH 1.5A | 5/**£1** |
| NEW BT PLUG + LEAD | **£1.50** |
| 1.25" PANEL FUSEHOLDERS | 3/**£1** |
| CHROMED STEEL HINGES 14.5 x 1" OPEN | **£1 each** |
| 12v 1.2w small wire ended lamps fit AUDI VW TR7 SAAB VOLVO | 10/**£1** |
| 12V MES LAMPS | 10/**£1** |
| STEREO CASSETTE HEAD | **£2** |
| MONO CASS.HEAD **£1** ERASE HEAD | **50p** |
| THERMAL CUT OUTS 50 77 85 120°C | **£1 ea** |
| THERMAL FUSE 121°C 240V 15A | 5/**£1** |
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| TO-3 TRANSISTOR COVERS | 10/**£1** |
| STICK ON CABINET FEET | 30/**£1** |
| PCB PINS FIT 0.1" VERO | 200/**£1** |
| TO-220 micas + bushes | 10/**50p** 100/**£2** |
| TO-3 micas + bushes | 15/**£1** |
| PTFE min screened cable | 10m/**£1** |
| Large heat shrink sleeving pack | **£2** |
| CERAMIC FILTERS 6M/9M/10.7M | **50p** 100/**£20** |
| MAINS LEAD WITH MOULDED 13A PLUG AND IEC SOCKET | **£1.50** |
| IEC chassis plug rfi filter 10A | **£3** |

Potentiomenters short spindles values 2k5 10k 25k 1m

| | |
|---|---|
| **2M5** lin | 5/**£1** |
| 500k lin 500k log | 4/**£1** |
| 40Khz ULTRASONIC TRANSDUCERS EX-EQPT NO DATA | **£1**/pr |
| PLESSEY INVERTER TRANSFORMER | **50 CYCLES** |
| 11.5-0-11.5V to 240v 200VA | **£6 (£3)** |

## DIODES AND RECTIFIERS

| | |
|---|---|
| 1N4148 | 100/**£1.50** |
| 1N4004/SD4 1A 300V | 100/**£3** |
| 1N5401 3A 100V | 10/**£1** |
| BA158 1A 400V fast recovery | 100/**£3** |
| BA159 1A 1000V fast recovery | 100/**£4** |
| 120V 35A STUD | **65p** |
| BY127 1200V 1.2A | 10/**£1** |
| BY254 800V 3A | 8/**£1** |
| BY255 1300V 3A | 6/**£1** |
| 6A 100V SIMILAR MR751 | 4/**£1** |
| 1A 800V BRIDGE RECTIFIER | 4/**£1** |
| 4A 100V BRIDGE | 3/**£1** |
| 6A 100V BRIDGE | 2/**£1** |
| 8A 200V BRIDGE | 2/**£1.35** |
| 10A 200V BRIDGE | **£1.50** |
| 25A 200V BRIDGE **£2** | 10/**£18** |
| 25A 400V BRIDGE **£2,50** | 10/**£22** |

## SCRS

| | |
|---|---|
| PULSE TRANSFORMERS 1:1+1 | **£1.25** |
| 2P4M EQUIV CI06D | 3/**£1** |
| MCR72-6 10A 600V SCR | **£1** |
| 35A 600V STUD SCR | **£2** |
| TICV106D 800mA 400V SCR | 3/**£1** 100/**£15** |
| MEU21 PROG. UNIJUNCTION | 3/**£1** |

## TRIACS ........................ DIACS 4/£1

| | |
|---|---|
| BT137-600 8A TO-220 | 2/**£1** |
| BT138-600 12A TO-220 | **70p** |
| NEC TRIAC AC08F 8A 600V TO220 | 5/**£2** 100/**£30** |
| TXAL225 8A 400V 5mA GATE | 2/**£1** 100/**£35** |
| TRAL2230D 30A 400V ISOLATED STUD | **£4 each** |

## CONNECTORS

| | |
|---|---|
| D25 IDC SOCKET FUJITSU | **£2** |
| 34 way card edge IDC CONNECTOR (disk drive type) | **£1.25** |
| CENTRONICS 36 WAY IDC PLUG | **£2.50** |
| CENTRONICS 36 WAY IDC SKT | **£4.00** |
| BBC TO CENTRONICS PRINTER LEAD 1.5M | **£3.50** |
| CENTRONICS 36 WAY PLUG SOLDER TYPE | **£4** |
| USED CENTRONICS 36W PLUG+SKT | **£3** |

## USED D CONNECTORS price per pair

D9 **60p**, D15 **£1.50**, D25 **£2**, D37 **£2**, D50 **£3.50** covers **50p ea.**

## WIRE WOUND RESISTORS

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|---|---|
| **W21** or sim 2.5W 10 of one value | **£1** |
| R10 OR15 OR22 2R0 4R7 5R0 5R6 8R2 10R 12R 15R 18R 20R 22R 27R 33R 47R 56R 62R 91R 120R 180R 390R 430R 470R 680R 820R 910R 1K15 1K2 1K5 1K8 2K4 2K7 3K3 3K0 5K0 R05 (50 milli-ohm) 1% 3w | 4 FOR **£1** |
| **W22** or sim 6W 7 OF ONE VALUE | **£1** |

R47 R62 1R0 1R5 1R8 3R3 6R8 9R1 12R 20R 24R 27R 33R 51R 56R 62R 68R 100R 120R 180R 220R 390R 560R 620R 910R 1K0 1K2 1K5 1K8 2K2 2K7 3K3 3K9 4K7 8K2 10k 15K 16K 20K

| | |
|---|---|
| **W23** or sim 9W 6 of one value | **£1** |

R22 R47 1R0 1R1 56R 62R 100R 120R 180R 220R 300R 390R 680R 1KO 1K5 5K1 10K

| | |
|---|---|
| **W24** or sim 12W 4 OF ONE VALUE | **£1** |

R50 2R0 9R1 18R 22R 27R 56R 68R 75R 82R 100R 150R 180R 200R 220R 270R 400R 620R 1K0 6K8 8K2 10K 15K

## PHOTO DEVICES

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|---|---|
| SLOTTED OPTO-SWITCH OPCOA OPB815 | **£1.30** |
| 2N5777 | **50p** |
| TIL81 PHOTO TRANSISTOR | **£1** |
| TIL38 INFRA RED LED | 5/**£1** |
| 4N25, OP12252 OPTO ISOLATOR | **50p** |
| PHOTO DIODE **50p** | 6/**£2** |
| MEL12 (PHOTO DARLINGTON BASE n/c) | **50p** |
| RPY58A LDR **50p** ORP12 LDR | **70p** |
| LEDs RED 3 or 5mm 12/**£1** | 100/**£6** |
| LEDs GREEN OR YELLOW 10/**£1** | 100/**£6.50** |
| LEDS ASSORTED RD/GN/YW + INFRA/RED | 200/**£5** |
| FLASHING RED OR GREEN LED 5mm **50p** | 100/**£35** |

## STC NTC BEAD THERMISTORS

| | |
|---|---|
| G22 22OR, G13 1K, G23 2K, G24 20K, G54 50K, G25 200K, G16 1M, RES @ 20°C DIRECTLY HEATED TYPE | **£1 ea** |
| **FS22BW NTC BEAD INSIDE END OF 1"** GLASS PROBE RES @ 20°C 200R | **£1 ea** |
| **A13 DIRECTLY HEATED BEAD THERMISTOR 1k res. Ideal for audio Wien** | **£2 ea** |

## CERMET MULTI TURN PRESETS ¾"

| | |
|---|---|
| 10R 20R 100R 200R 250R 500R 2K 2K2 2K5 5K 10K 47K 50K 100K 200K 500K 2M2 | **50p each** |

## IC SOCKETS

6 pin 15/**£1** 8 pin 12/**£1** 14/16 pin 10/**£1** 18/20 pin 7/**£1**, 22/24/28 pin 4/**£1** 40 pin **30p**

## SOLID STATE RELAYS

| | |
|---|---|
| 40A 250V AC SOLID STATE RELAYS | **£18** |

## POLYESTER/POLYCARB CAPS

| | |
|---|---|
| 100n 63v 5mm | 20/**£1** 100/**£3** 1000/**£25** |
| 1n/3n3/5n6/8n2/10n 1% 63v 10mm | 100/**£6** |
| 10n/15n/22n/33n/47n/68n 10mm rad | 100/**£3.50** |
| 100n 250v radial 10mm | 100/**£3** |
| 100n 600v sprague axial 10/**£1** | 100/**£6 (£1)** |
| 2u2 160v rad 22mm | 100/**£10** |
| 10n/33n/47n 250v ac x rated 15mm | 10/**£1** |
| 470n 250v ac x rated rad | 4/**£1** |
| 1U 600V MIXED DIELECTRIC | **50p ea.** |

## RF BITS

| | |
|---|---|
| MINIATURE CO-AX 50Ω URM95 | 100m/**£12** |
| 12 volt CO-AXIAL relays sim. RS 349-686 Ex-equipment, with BNC tails | **£6** |
| TRIMMER CAPS ALL | **4/50p** |

SMALL 5pf 2 pin mounting 5mm centres

| | |
|---|---|
| SMALL MULLARD 2 to 22pF | **4/50p** |
| SMALL MULLARD 5 to 50pF | **4/50p** |

larger type grey 2 to 25pF black 15 to 90pf

| | |
|---|---|
| TRANSISTORS 2N4427 | **60p** |
| FEED THRU CERAMIC CAPS 1000pF | 10/**£1** |

## MINIATURE RELAYS Suitable for RF

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|---|---|
| 5 volt coil 1 pole changeover | **£1** |
| 5 volt coil 2 pole changeover | **£1** |
| 12 volt coil 1 pole changeover | **£1** |

## MONOLITHIC CERAMIC CAPICITORS

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|---|---|
| 10n 50v 2.5mm | 100/**£4.50** |
| 100n 50v 2.5mm or 5mm | 100/**£6** |
| 100n ax short leads | 100/**£3** |
| **100n ax long leads** | 100/**£6** |
| 10n 50v dil package 0.3" rad | **£4**/100 **£35**1000 |
| 100n 50v dil package 0.3" rad | **£10**/100 |

## STEPPER MOTORS

| | |
|---|---|
| 4 PHASE 2 9V WINDINGS | **£3.50** |

# KEYTRONICS

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65p OTHERWISE (LIGHT) ITEMS

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# BARGRAPH TACHOMETER

### By Chris Walker BSc

**First for the revolutions, best for unidentified rattles, checks that engine-speed.**

It is commonly expressed among sympathetic car owners that the meagre bunch of panel warning lights fitted to the majority of today's cars do not give sufficient information as to what is happening under the bonnet. Realistically speaking, a low oil pressure warning lamp lighting at 70 mph spells disaster for your engine, whereas an oil pressure gauge of some description should give advance warning of a progressive drop in system pressure at lower speeds. Similarly, by keeping an eye on the rising engine temperature while ascending a long steep hill (especially when towing) the driver can choose the best place to stop and rest the car, whereas a curt red 'STOP-HIGH TEMP' light can be most inconvenient.

Therefore, many attentive drivers will sooner or later begin to fit add-on gauges and dials until the instrument panel ends up looking like the flight-deck of Concorde.

Of course, there is the other breed of car owner who couldn't really care less what is happening to the engine. They never check fluid levels or tyre pressures, and as long as the darned thing starts every morning and never lets them down then why complain?

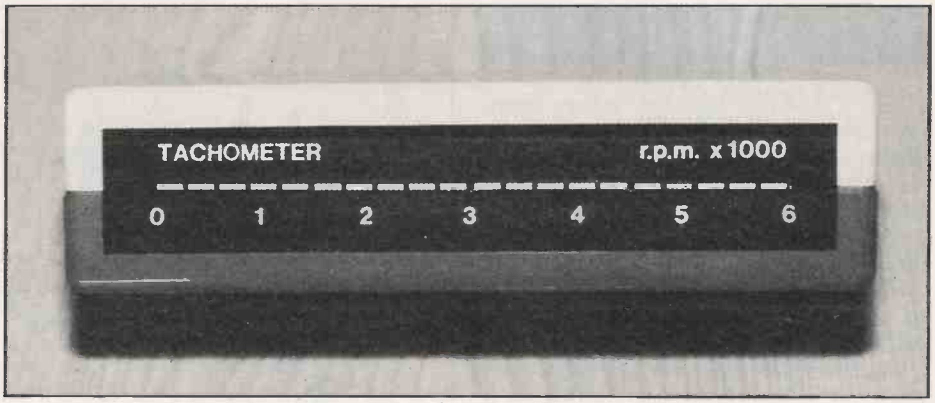
## TACHOMETERS

One instrument that cannot be replaced by a simple warning lamp is the tachometer or rev-counter. This instrument is usually only fitted to the higher price-bracket or high performance vehicles but it is surprisingly useful in any car. A tachometer displays the speed at which the engine crankshaft rotates, in revolutions per minute (rpm). Obviously engine speed is related to road speed, but the exact link between the two depends on the gear engaged.

All petrol engines have a characteristic speed at which they produce their maximum output power: the power peak. This figure can sometimes be found in the owner's handbook and, along with the tachometer, it can be used to time gear changes accurately to obtain the best performance from your engine. For example, a large number of drivers will start an overtaking manoeuvre in third gear, but then change into fourth part way through, wasting the vital acceleration necessary to overtake swiftly and safely.

Those of us content to settle for more mediocre performance can find the tachometer helpful for indicating clutch slip or wheelspin on snow covered roads. It is also invaluable when trying to locate that annoying but elusive rattle which only occurs at certain revs.

Whatever your reason for fitting such an instrument, the colourful but elegant display of the Bargaph Tachometer described here makes it an attractive module for any vehicle.



## SPECIFICATION

Most revcounters are of the moving-coil type using a revolving needle on a circular scale. There are many disadvantages for the home-constructor using such a display because large circular meters are difficult to obtain, expensive, delicate and bulky. The cheap panel milliammeter is not an attractive alternative.

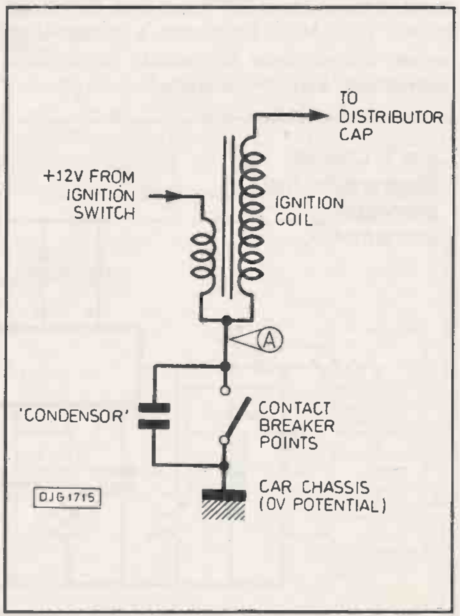
Some manufacturers have equipped a few of their vehicles with electronic dashboard instruments reading on digital or bargraph displays. A digital read-out, although accurate, is difficult to read at a glance and it is not easy to interpret the trend of a changing figure, whether increasing or decreasing. Also, one has to decide between a slow response time or a continuously updated, changing display. Bargraphs, however, are a good compromise between digital and analogue displays and their linearity enables a slimline and attractive unit to be constructed.

The Bargraph Tachometer uses a three-colour 20 led bargraph display, showing green up to 3000 rpm, yellow between 3000 and 4500, and red above 4500 rpm. Connoisseurs may comment at this lowish 'red-line' figure: many tachometers enter the red warning region at about 5500 rpm or higher, but the exact figure obviously depends on the particular vehicle. Anyway, spare a thought for your poor engine: at 6000 rpm each piston oscillates up and down in its cylinder 100 times every second. The circuit shown will full scale deflect (ie, light all the leds) at 6000 rpm on a four cylinder engine, but only one resistor needs to be modified for a six cylinder unit.

The response time of the circuit is fast enough to keep up with the inertia of most road-car engines and so it gives a reliable indication of engine speed under all conditions.

Accuracy is typically 5% with the recommended components, and the entire unit is easy to fit; only three electrical connections are needed, all on the ignition coil. This should eliminate the painful contortions needed to get one's head under the dashboard, and the even more painful ones to get it out!

**Fig 1. Basic 'low tension' ignition circuit.**



## IGNITION PULSES

Fig. 1 shows the basic low voltage circuit of a petrol vehicle ignition system with negative earth (the unit can also be fitted in the less common positive earth cars, see later). The contact breaker points are a mechanical switch operated by a car on the distributor drive shaft. In practice, the 'points' in very many new cars are replaced by an electronic ignition system of some sort but the principle of operation is the same.

As the engine turns over, the points open and close; when closed, point A (Fig. 1) is pulled down to 0V and current flows through the primary winding of the coil. As the points open the current is abruptly stopped and the sudden collapse of magnetic field around the primary coil induces very high voltage oscillations in the primary circuit, see Fig. 2a. This 'ringing' lasts for about 1 millisecond and is stepped up to several tens of thousands of volts in the secondary coil to produce a spark at the spark plugs. Incidentally, the ringing produced when the primary current is cut off is *similar* to the knocking sometimes heard in loose plumbing when a water tap is suddenly turned off.

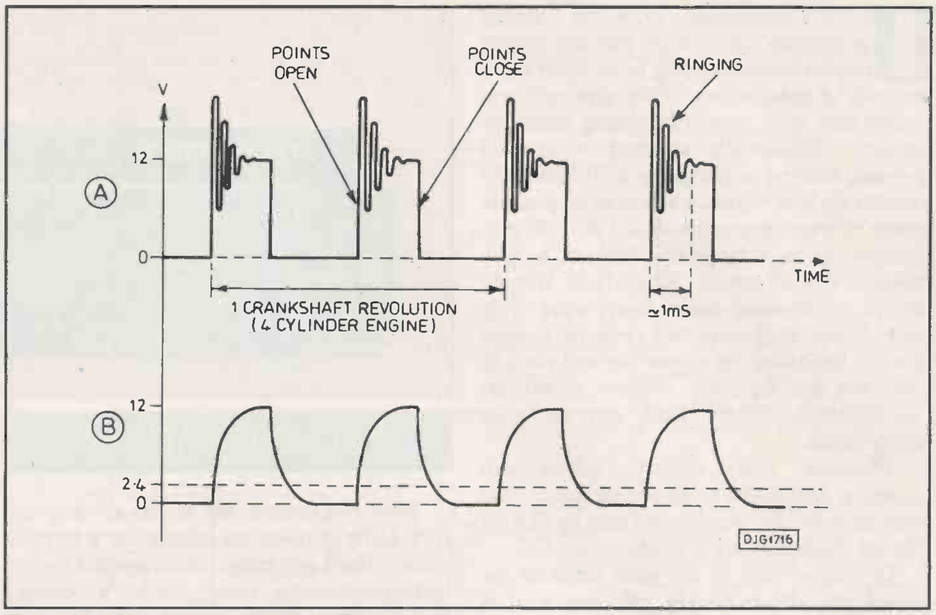


**Fig 2 (a). Signal at point A in Fig 1.**
**Fig 2 (b). Signal at point B in Fig 3.**

## F-V CONVERTER

With reference to the main circuit diagram in Fig. 3, the pulses from point A on the ignition coil are fed through resistor R1 to point B. Capacitor C1 smooths out the edges of the pulses as shown in Fig. 2b and prevents the ringing of the coil from reaching the LM2917 frequency-to-voltage converter ICI. This is necessary otherwise each ring may be counted as an opening of the points, giving a false tachometer reading. Zener diode D1 'clips' the input pulses to a maximum of 12V, protecting IC1 from damage.

The signal at pin 1 of IC1 is compared to the fixed 2.4V reference at pin 11 derived from zener diode D2 and resistor R6. One complete cycle occurs every time the voltage at pin 1 rises above 2.4V and then falls back below. The LM2917 generates a voltage $V_{out}$ at its output (pin 5) which is directly proportional to the pulse frequency on pin 1:

$$V_{out} = 7.56 \times R3 \times C2 \times f$$

Where f = pulse freq (Hz), R3 is in ohms and C2 in farads.

Since, in a four cylinder engine, two pulses will be produced for every crankshaft revolution then at 6000 rpm, f=200Hz and so Vout = 2.7V, approximately. *For a six cylinder engine the same range can be accommodated by changing R3 to a value of 68k.*

Capacitor C3 smooths the output signal from IC1 and stops display flicker, although some ripple is inevitable, especially at low frequencies. Increasing the value of C3 will reduce this but it also has the effect of slowing the response time of the circuit.

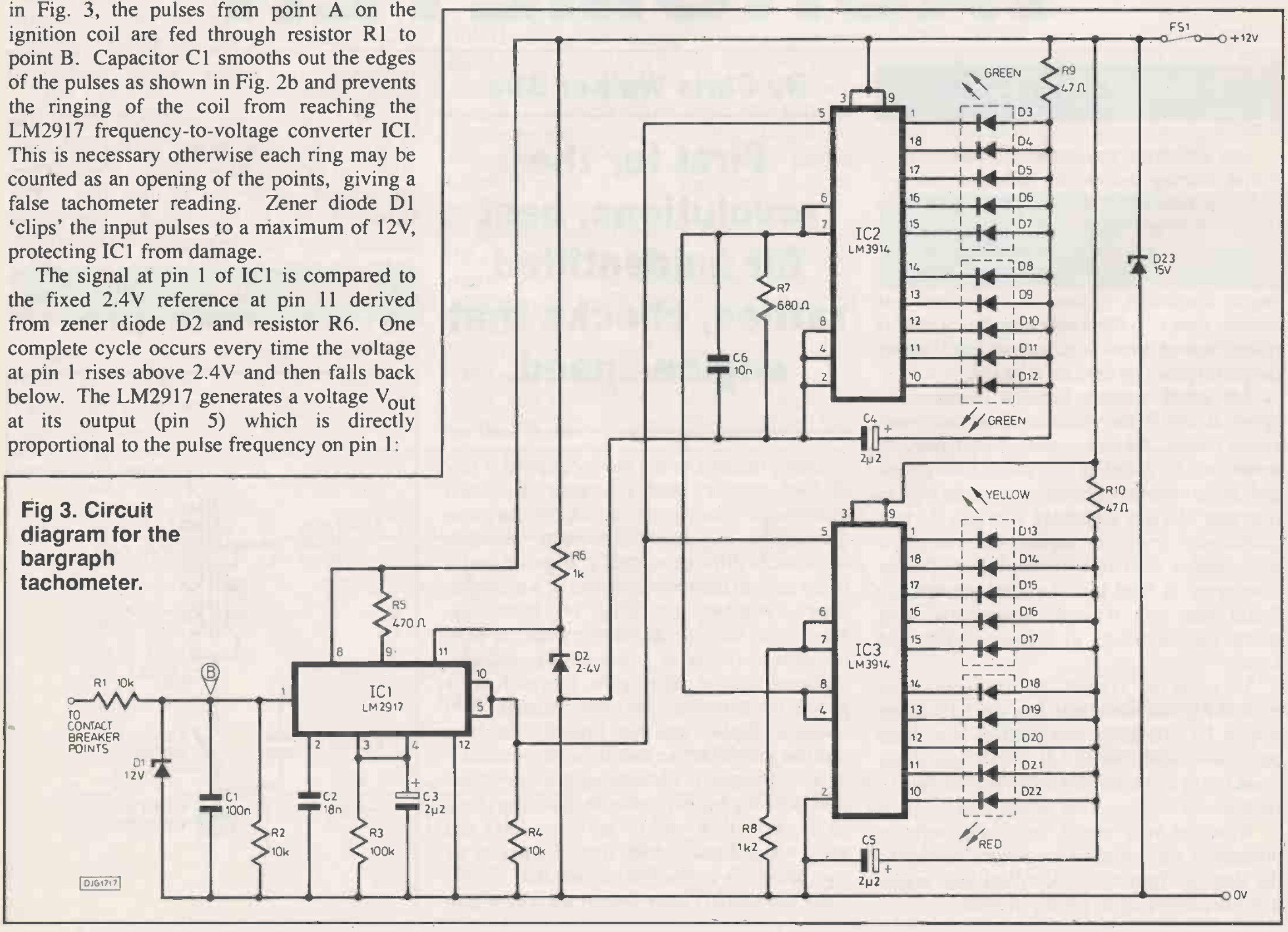


**Fig 3. Circuit diagram for the bargraph tachometer.**

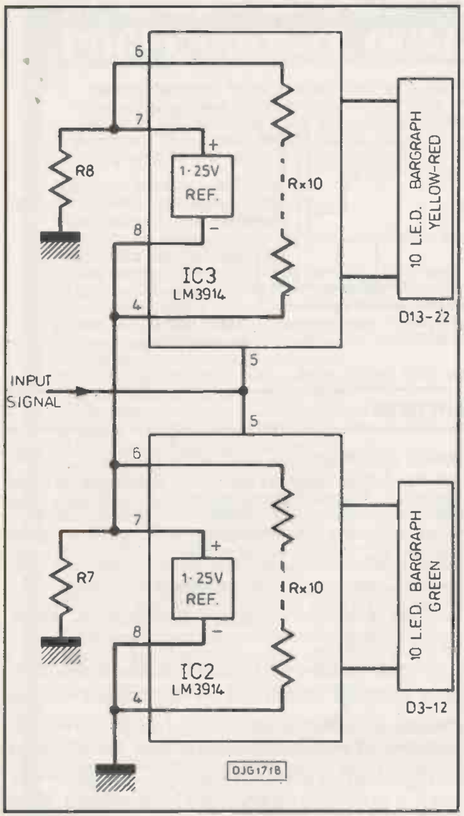


**Fig 4. Method of chaining two 10 - LED bargraph displays.**

Therefore, a compromise has to be made in this respect.

The LM2917 is available in 8-pin and 14-pin dil versions. *The 14-pin device must be used in this design* since the input on the 8-pin version is internally ground referenced.

## BARGRAPH DISPLAYS

Two LM3914 linear bargraph display driver ics are used, each one controlling ten led's.

The output voltage from IC1 is fed into the signal input of the bargraph displays, pin 5 IC2 and IC3. Each ic contains a string of ten identical resistors across which is placed a 1.25V reference obtained from pins 7 and 8, see Fig. 4. As the voltage on pin 5 exceeds the potential at the top end of each resistor an extra led is made to light. Notice how, by connecting the low potential end of the resistor chain in IC3 to the high end of IC2, leds D3 to D12 will light in sequence as the pin 5 voltage rises from 0 to 1.25V followed by D13 to D22 for a rise from 1.25V to 2.50V.

The display ics automatically control the led current and series resistors are not required on each output. The current through each led is about ten times the current drawn from pin 7 of the ic. It has been found that about 20mA lights the diodes sufficiently brightly to give good daytime visibility without needing dimming at night. Hence, since negligible current flows through the internal resistor chain, all the current from pin 7 of IC2 and IC3 flows through resistors R7 and R8 respectively. So, considering IC2, for a 20mA led current the current from pin 7 has to be:

$$I = \frac{V}{R7} = \frac{1.25}{680} = 1.8\text{mA} \quad (\approx \frac{20\text{mA}}{10})$$

and similar for IC3, bearing in mind there is 2.5V across R8 because of the two resistor chains in series.

Resistors R9 and R10 are 3W wirewound types used to dissipate some power when several leds are lit and prevent overheating of IC2 and IC3.

Capacitors C4, C5 and C6 help to stabilise the display circuits by decoupling various points to earth. In practice, the only sure way to prevent parasitic oscillations when using these bargraph display chips is to connect the earthed side of the capacitors as close to pin 2 as possible. It is for this reason that C4 and C5 are mounted underneath the circuit board.

Finally, zener diode D23 together with fuse FS1 protect the circuit from reverse polarity connection or over-voltages which could be caused by transients or a faulty charging circuit on the car.

## CONSTRUCTION

All the components are mounted on a single-sided printed circuit board measuring 140x65mm which is mounted upside-down in the case. The foil pattern for the pcb is given in Fig. 5. Since there are no internal connecting wires the unit is very simple to construct.

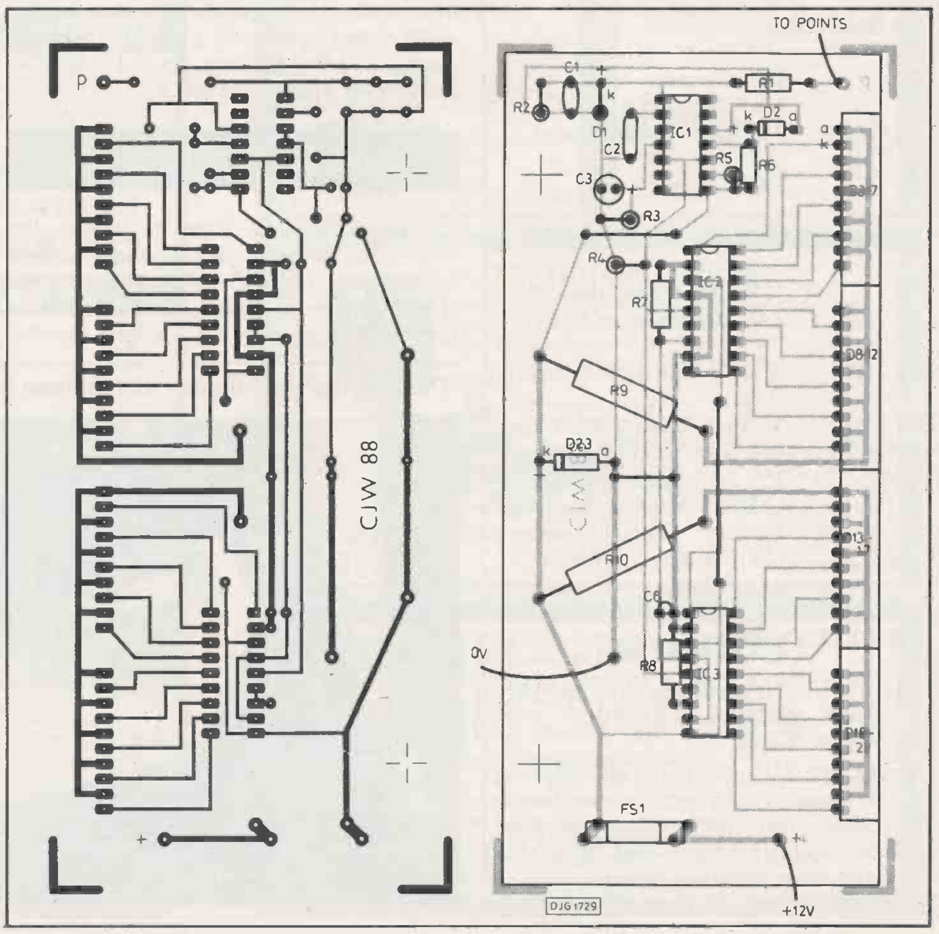
With reference to Fig. 6, begin by soldering into place the small components: resistors, capacitors and zener diodes, checking the polarity of the diodes and tantalum capacitor C3. Insert the three wire links, the ic holders, fuse clips and three terminal pins for alter connection to the vehicle. It is a good idea to solder capacitors C4 and C5 to the under-side of the board at this stage, but notice that the negative lead must be soldered directly to the pin 2 pcb pad. When this part of assembly is complete insert the two wirewound resistors R9 and R10: they should be mounted about 1cm above the board to allow air to circulate around them as they can become quite hot!

The pcb has been designed to accept four 5-led displays, two green D3-D7 and D8-D12, one yellow D13-D17 and one red D18-D22. These have to be mounted on the pcb with their windows facing sideways, as in Fig. 7. Start with the green display containing D3 to D7 and, holding it horizontally with the leads towards the bottom, bend all leads around a matchstick so that they point vertically downwards with about 2mm of lead protruding from the device before the bend. When mounted on the pcb the main body of the display should be flush with the front of the board. Use a little adhesive to ensure the display sits flat on the board and then, trying not to overheat the device, solder all ten connections. Repeat for the other displays.

Insert the ics into their holders: no special handling precautions are necessary but make sure they are inserted the correct way round.

The circuit board is mounted inside a clip-

**Figs 5 and 6. PCB track and component layouts. Note that these are shown less than life size – the pin spacing for the ICs is 0.1 inch. C4 and C5 should be hard wired to the track side of the PCB, polarity as shown in Fig 3.**



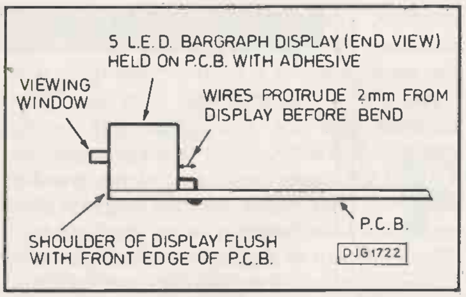


**Fig 7. Mounting detais for the display LEDs.**

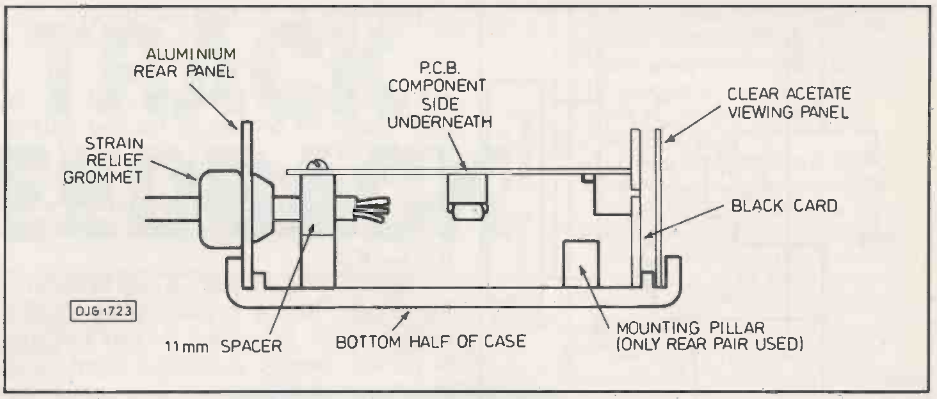


**Fig 8. Mounting of PCB/viewing assembly in case.**

together Verbox type 211 measuring 153x84x40mm. This is a two-tone plastic case with removable aluminium side panels. Since it would be difficult to cut a precise rectangular slot into aluminium for the bargraph display to protrude through, it was decided to completely remove the front aluminium panel and replace it with a piece of clear, 1mm thick rigid acetate sheet (available from any good model shop) to act as a viewing window. The displays then protrude through a slot cut in a piece of black card mounted behind the window. The slot is easy to cut in card using a sharp knife.

## COMPONENTS

### RESISTORS

| | |
|---|---|
| R1,R2,R4 | 10k (3 off) |
| R3 | 100k |
| R5 | 470R |
| R6 | 1k |
| R7 | 680R |
| R8 | 1k2 |
| R9,R10 | 47R 3 watt wirewound (2 off) |

All 0.25W carbon, 5% unless otherwise stated.

### CAPACITORS

| | |
|---|---|
| C1 | 100n Ceramic |
| C2 | 18nF Polyester layer 5% |
| C3,C4,C5 | 2.2µF 35V Tantalum bead (3 off) |
| C6 | 10nF Ceramic |

### SEMICONDUCTORS

| | |
|---|---|
| D1 | 12V 500mV zener diode |
| D2 | 2.4V 500mW zener diode |
| D3-D7,<br>D8-D12 | Green 5-led bargraph display (2 off) |
| D13-D17 | Yellow 5-led bargraph display |
| D18-D22 | Red 5-led bargraph display |
| D23 | 15V 1.3W zener diode |
| IC1 | LM2917 Frequency to voltage converter, 14-pin dil version |
| IC2,IC3 | LM3914 Bargraph display driver (2 off) |

### MISCELLANEOUS

| | |
|---|---|
| FS1 | 1A 20mm fast blow fuse and pcb mounting holder. |

Verbox type 211, pcb, 14-pin dil socket, 18 pin dil socket (2 off); terminal pins; thin 3-core cable, strain relief grommet, 1mm thick acetate sheet, rigid black card, white rub-down lettering, mountings to suit.

Because the displays are partially cowled by the case they are easier to view in bright ambient lighting and also there is a good contrast between them and the black card backing. Last, but not least, this method of mounting gives a professional look, especially if the card is labelled with white rub-down lettering, as shown in the photographs.

Thin 3-core mains cable is used to connect the unit to the vehicle. Solder the conductors to the terminal pins remembering to make a note of which colour represents which connection! A single hole needs drilling in the rear aluminium panel through which the cable passes, via a strain relief grommet.

Using the two rear mounting pillars in the box, screw the pcb/black card assembly in the case (with the component side downwards) using 11mm spacers to place the bargraph display mid-way between top and bottom of the viewing window, see Fig. 8.

## VEHICLE MOUNTING

Find a suitable place to mount the tachometer, preferably not in direct sunlight for viewing reasons, although the driver should not have to deviate his eyes far from the road in order to read the display. Double-sided self-adhesive pads may be found useful to hold the unit in place. Take the 3-core cable through to the engine compartment and route it to the ignition coil. Take great care to keep the cable away from areas which become hot such as the exhaust manifold.

*The following applies to negative earth vehicles only:*

Remove the +ve terminal from the battery: this is most important as a mistake during wiring could be disastrous. Car batteries are capable of delivering a current of hundreds of amps which would very rapidly and painfully melt a gold ring inadvertently causing a short circuit.

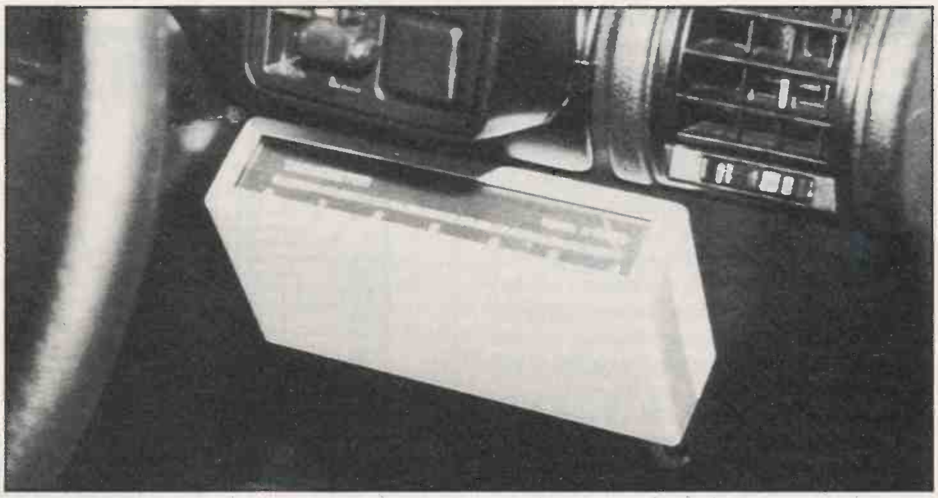
The +12 line on the tachometer goes to the 'live' side of the coil, sometimes marked with a '+' sign. This connection is controlled by the ignition switch ensuring that the unit is only switched on with the ignition circuit. Connection should be made using a 'piggy-back' slide-on connector, or 'Scotch Blocks' can be used to splice into the existing wires. The signal input lead is connected to the points side of the coil (marked '-') and the 0V wire is connected to the metal bodywork by trapping it under one of the coil mounting bolts.

*For positive earth cars, the only modification is to connect the +12 wire to the car chassis and 0V goes to the live side of the coil.*

Reconnect the battery, start the engine and off you go!

Please drive sensibly and safely. PE

**The bargraph tachometer as mounted in the author's car.**



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## VOLUME 25

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## Books reviewed during 1989

**All-Time Favourite Electronic Projects**. Delton T. Horn. Tab Books. **September**

**Audio IC Circuits Manual.** R.M. Marston. Heinemann Newnes. **December**

**Build Your Own 80386 IBM Compatible and Save a Bundle**. Aubrey Pilgrim. Tab Books. **December**

**Chambers Science and Technology Dictionary**. Chambers Cambridge University Press. **January**

**Complete Electronics Career Guide**. Joe Risse. Tab Books. (Applicable to USA careers and not recommended for UK readers.) **December**

**Computers and Music**. R.A. Penfold. PC Publishing. **December**

**Computer Hobbyists Handbook**. R.A. and J.W. Penfold. Babani. **December**

**Concise Introduction to UNIX**. N. Kantaris. Babani. **September**

**Designing DC Power Supplies**. G.C.Loveday. Benchmarks. **January**

**Designing with Linear ICs.** G.C. Loveday. Benchmarks. **December**

**Digital Audio and Compact Disc Technology**. Sony Service Centre. Heinemann Newnes. **January**

**Digital IC Handbook**. Michael S. Morley. Tab Books. **December**

**Digital Logic Gates and Flip-Flops**. Ian R. Sinclair. PC Publishing. **September**

**Electronics Build and Learn**. R.A. Penfold. PC Publishing. **January**

**Electronic Circuit Design - Art and Practice**. T.H. O'Dell. Cambridge University Press. **January**

**Encyclopaedia of Electronic Circuits - Volume One**. Rudolf F. Graf. Tab Books. **December**

**Encyclopaedia of Electronic Circuits - Volume Two**. Rudolf F. Graf. Tab Books. **September**

**Enhanced Sound - 22 Projects for the Audiophile**. Richard Kaufman. Tab Books. **June**

**Experiments in Artificial Neural Networks.** Ed Reitman. Tab Books. **January**

**Experiments in CMOS Technology.** Dave Prochnow and D.J. Banning. Tab Books. **July**

**Experiments with Eproms**. Dave Prochnow. Tab Books. **June**

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**How to Make Printed Circuit Boards**. Calvin Graf. Tab Books. **July**

**Illustrated Dictionary of Electronics - 4th Edition.** R.P. Turner & S. Gibilisco. Tab Books. **January**

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**Remote Control Handbook**. Owen Bishop. Babani. **June**

**Satellite Television Installation Guide**. John Breeds. Swift TV Publications. **June**

**Soft Ferrites - Properties and Applications - 2nd Edition**. E.C. Snelling. Butterworths. **December**

**Superconductivity**. Jonathan L. Mayo. Tab Books. **July**

**Synthesisers for Musicians**. R.A. Penfold. PC Publishing. **July**

**Teach Yourself Electronics**. Malcolm Plant. Teach Yourself Books (Hodder and Stoughton). **June**

**Troubleshooting and Repairing TVRO Systems**. Stan Prentiss. Tab Books. **June**

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**Cambridge University Press**. The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 0223 312393.

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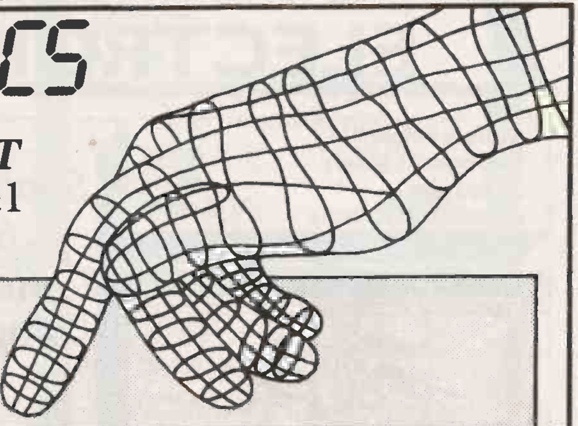

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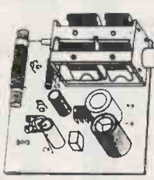

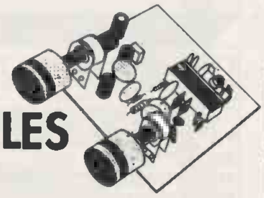

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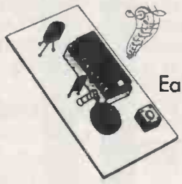

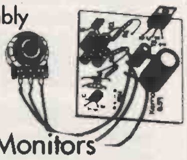

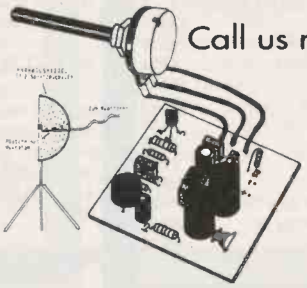

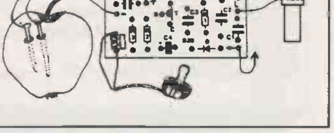

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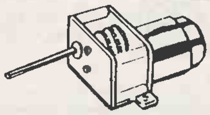

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# PE CHRISTMAS CROSSWORD

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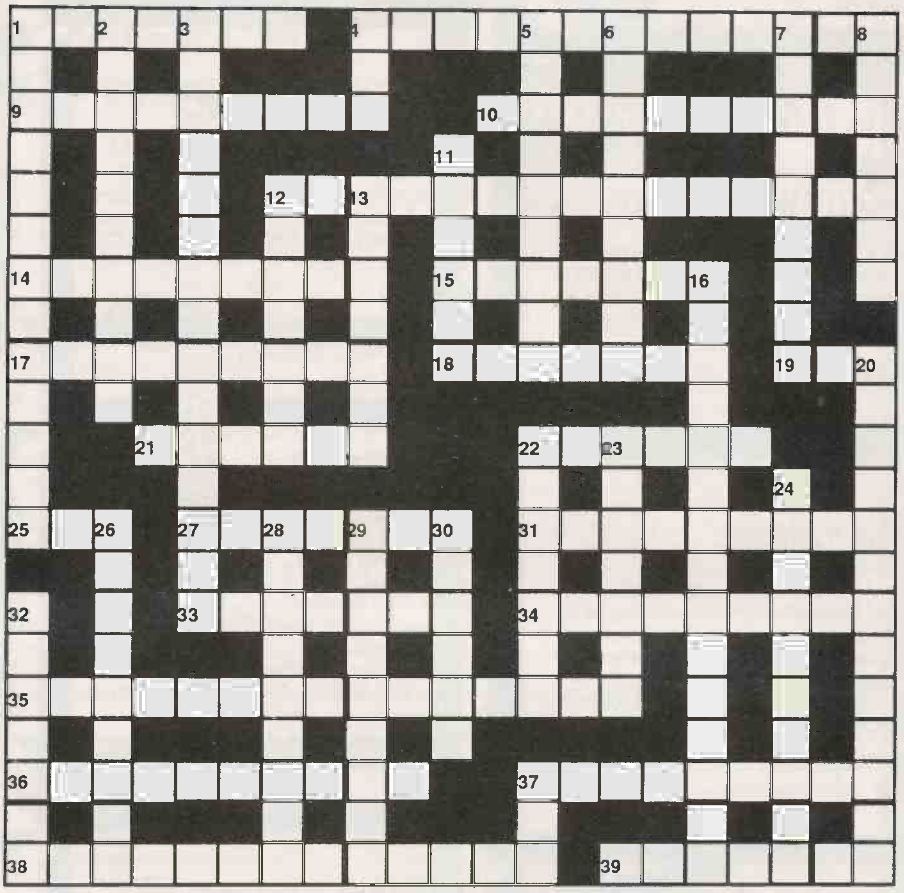
**Answers next month (but no prizes!)**



CLUES ACROSS

1) Unit of charge (7).
4) I trace fiction, mix up and become an ac to dc conversion process. (13).
9) Strength of an electric field. (9).
10) Pin 6 of LM325, or your eye, perhaps. (5,5).
12) Detection system providing three-dimensional positional information (10,5)
14) ICI troops change to describe substance with same properties in all directions (9).
15) Most likely cause of a flat battery! (4,3)
17) Sum up the fries? Yes, and a tally of IC packages. (4,5).
18) Voltage induced in current carrier by magnetic field, or passage-way potential? (4,3).
19) Electrostatic Voltmeter. (1,1,1).
21) Prejudiced way of establishing potentials? (6)
22) Silicon-controlled rectifiers (6).
25) Fixed data storage device. (3)
27) Inverter. (3,4).
31) Next I risc, confused external properties. (9)
33) Napolean Bonaparte was his student. A transformed French mathematician? (7)
34) Early form of digital communication. (5,4)
35) Constituent parts of popular, polarised capacitor. (4,3,8)
36) Permission to enter, the reciprocal of 7 down. (10).
37) Waved a baton and passed the current. (9)
38) Check to determine parameter drift. (4,2,3,4).
39) Stay indoors to have knowledge of company finance. (7)

DOWN

1) Beknighted entrepreneur, and PE contributor! (5,8)
2) Above audio frequency. (10)
3) Antenna effective in all positions. (15)
4) Beam (3)
5) Latent voltage source, or room for lazy prisoners? (5,4)
6) Organisation where all professional engineers should be locked away? (9)
7) Reciprocal of 36 across, opposes ac. (9)
8) Resonance is normal. (7)
11) Flat, even effect of a reservoir capacitor. (6)
12) Gases. (7)
13) Found, as by 12 across, perhaps? (7)
16) Root-mean-square amounts. (9,6).
20) Device for storing melodies? (5,8).
22) Heat induced. (7).
23) Where the bits and bytes go. (2,2,3).
24) Membership class of 6 down. (10)
26) I'm small pi - a little current. (9)
28) Reeled information. (5,4).
29) Landslide breakdown? (9)
30) Electrical happenings. (6)
32) RF trace - in a way, bends the light. (7).
37) Computer aided engineering. (1,1,1).

# BIKE ALARM

## Tilt! Ding ding ding! Another bike thief thwarted.

### BY CHRIS BROWN

Own up. How many times have you not chained up your pushbike while you went into the shop for a few moments? Yet a few moments is all a thief would need to cycle off with your mode of transport. Yes, I know. It's such a hassle to chain it up every time ... but how about another deterrent? An alarm! Once it sounds, believe me, all eyes turn towards where the noise comes from, (as I can testify when I forget to disarm it, and attempt to "steal" my own bike!) Any would-be thief would be 'clocked' by several passers-by. What's more, the unit also doubles as a handy hooter; it's far louder than any ding-a-ling bell.

## SOUNDING CIRCUIT

Electronically speaking, initially, it's just one component that does the work – the handy ol' thyristor. This is helped along by another couple of components, plus some interestingly wired jack sockets. First of all, there's the "arm/disarm" jack. When the jack plug is in place, the alarm is off, but pressing the push button on top of the unit makes the sounder sing, ie it operates as a hooter. To arm the unit, you simply remove the jack. Now, when the wheel rotates, (because that's where the sensor is situated), the alarm will sound. And the only way to regain peace is to insert the jack plug to disarm it.

The sensor plugs into a multi function jack in the base of the unit. The sensor – a reed switch and magnet – acts as a normally open switch. When they close, the alarm sounds. Ahh, but here comes a clever thief. Surely, if he pulls out the sensor jack, the unit won't be able to sound. But how wrong he is! As soon as he removes the sensor jack, the alarm goes off! Even if he cuts the wire, chances are he'll short the two wires together, and ...

You never get owt for nowt in this life, and a large current drain is the consequence of a loud alarm. Rather than keep changing batteries, I decided to use nicad batteries. This also meant the unit could be assembled, and the case lid need never be removed again, which helps since constantly screwing and unscrewing self tapping screws into a plastic case invariably wears the thread out in time. Again, the multi-option jack at the bottom of the case serves as the charging point. Thus, you simply unclip sensor wire, take unit off bike, and take it indoors for a recharge!

## HOW IT WORKS

Taking the hooter option first. Power travels to the jack plug, out via the tip, around the internal link wire, and back into the unit via the sleeve contact. From here, it travels to the normally open push switch. When this is closed, power flows to the sounder, and back to the neg of the battery. Simple!

When the alarm option is chosen, ie the jack is removed, power is diverted via the jack's break contact to the anode of the thyristor. Power is also sent to the sensor via the other 3.5mm jack. Once the reed closes, current travels back, via the 1k resistor to the gate. The thyristor therefore turns on, and current travels through the sounder. The diode protects the thyristor from any back emf generated.

The sensor jack supplies a positive current out to the sensor via the tip of the jack, which comes back again via the ring of the jack, and so to the resistor. The positive is also connected to the normally open break

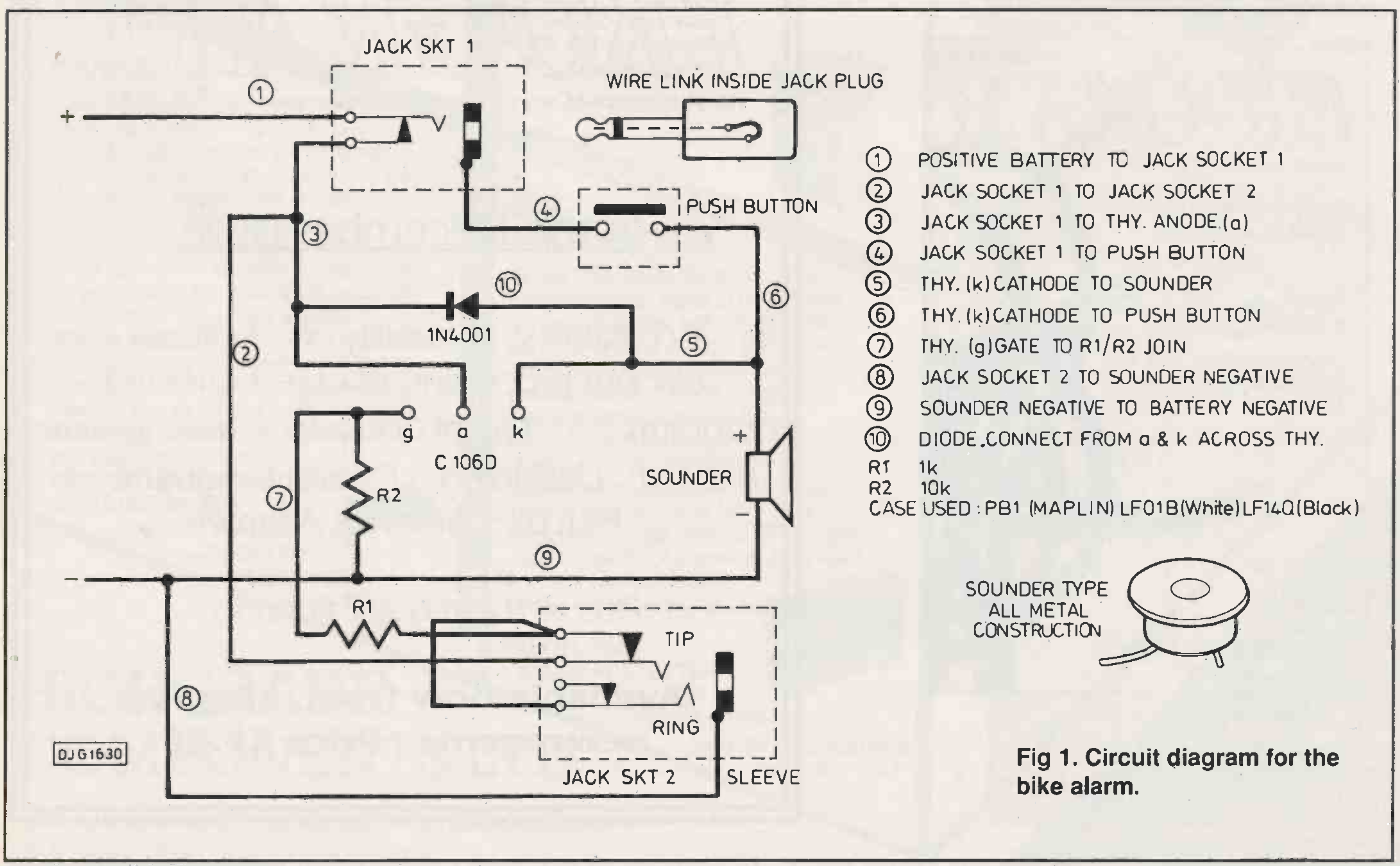


Fig 1. Circuit diagram for the bike alarm.

contact. When the jack is removed, the contact closes, and supplies current to the cold side of the resistor. When the charging plug is inserted, this connects to the positive line via the tip, and the negative via the sleeve connection.

## CONSTRUCTION

Place the sounder in the box, sounding side facing you. Push it up against the screw holding pillar, and measure from the *outside* of the case to middle of sounder. Place the sounder aside, and turn the case upside-down. Measure down from top of case, mark position and drill a 3mm hole. Open out using a 15mm wood drill or similar. With any luck, when you place the sounder behind this hole, it will line up centrally with its top edge resting against the screw pillar.

On the top face drill a 3mm hole, and on the left side another 3mm hole. Using a file, or the blade of a scissor to shear off plastic, open out these holes to accept the 3.5mm socket and the push button.

At the bottom end of case, insert battery holder, and press against the right side. There's a space to the left. Roughly midway across this area, mark and drill another 3mm hole. Open this out to accept the other 3.5mm jack socket. Finally, drill a hole in the lid to accept the device to attach unit to bike. A 22mm plastic pipe clip was used in the prototype.

Returning to the sounder hole, cut a 20mm piece of mesh, the type used to reinforce car body repairs. Glue this over hole. Next, mix some Araldite, and blob on the front of the sounder, avoiding central sounding mechanism. Place the unit in position, and press down. Leave this to set, usually in about 24hrs. The mesh helps to reduce the amount of rain which hits the sounder, but is only suitable for a light drizzle. When it really pours, it's best to temporarily tape over the sounder to avoid it going rusty. It will probably still work when rusty, but why risk ruining the unit?

## INTERWIRING

Once the hardware is out the way, it's simply a matter of interwiring the various components following the diagrams. Remember to solder the resistors across the lower 3.5mm jack, and the diode across the thyristor.

The sensor is simply a magnet mounted on the front wheel fork, (using Araldite again), and the reed fixed to the front spoke. How you mount the reed will be up to you. I mounted mine inside a ball point pen's plastic shell, then mounted this to a 3/8 inch pipe clip. The latter allows the reed to be moved closer to, or further away from the magnet in a horizontal plane. If you don't want to mess about with such a sensor, the new vibration switch from Maplin might be a better option. This switch stays open circuit in whatever position it comes to rest, but should it be moved, it closes, and operates the alarm. This sensor could be mounted inside the unit, making it self contained. The lower jack could then be replaced with a standard jack since it will only be required to provide a charging point.

## DISARMING

The arm/disarm jack also needs a little bit of configuring, but is simply the two contacts wired together internally. On my own version, I made sure the contacts stayed conducting by packing the inside of the body with tin foil. For neat appearance, the cut down body was then filled with plastic filler, although Araldite will again serve just as well.

## AIR CALL

*Has anyone an idea to help a forgetful editor who has his pump pinched through failing to remove it?!* **Ed.**

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**TLX700 Micro Miniature telephone transmitter.** Connects to line (anywhere) switches on and off with phone use. All conversations transmitted. 20mm x 20mm. Powered from line. 1000m range .......... **£12.95**

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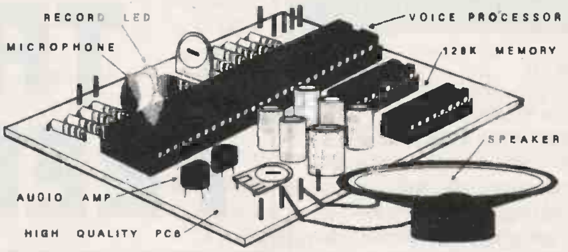

This simple to construct and even simpler to operate kit will record and playback short messages or tunes. It has many uses – seatbelt or lights reminder in the car, welcome messages to visitors at home or at work, warning messages in factories and public places, in fact anywhere where a spoken message is announced and which needs to be changed from time to time. Also suitable for toys – why not convert your daughter's £8 doll to an £80 talking doll!!

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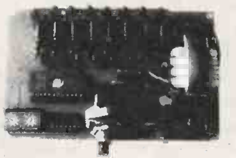

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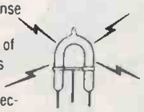

Produces an intense light pulse at a variable frequency of 1 to 15Hz. Includes high quality PCB, components, connectors. 5Ws strobe tube and assembly instructions. Supply: 240V ac. Size: 80 x 50 x 45.

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Includes all components (+transformer) for a sensitive IR receiver with 16 logic outputs (0 – 15V) which with suitable interface circuitry (relays, triacs, etc – details supplied) can switch up to 16 items of equipment on or off remotely. Outputs may be latched to the last received code or momentary (on during transmission) by specifying the decoder IC and a 15V stabilised supply is available to power external circuits. Supply: 240V AC or 15 – 24V DC at 10mA. Size (exc. transformer) 9 x 4 x 2 cms. Companion transmitter is the MK18 which operates from a 9V PP3 battery and gives a range of up to 60ft. Two keyboards are available – MK9 (4-way) and MK10 (16-way).

| | |
|---|---|
| MK12 IR Receiver (inc transformer) | **£17.00** |
| MK18 Transmitter | **£7.80** |
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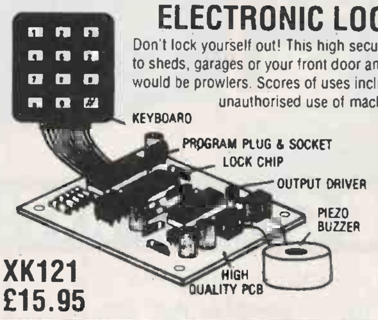

Don't lock yourself out! This high security lock kit will secure doors to sheds, garages or your front door and the built-in alarm will deter would be prowlers. Scores of uses including area access preventing unauthorised use of machinery or even disabling your car. One correct 4 digit code (out of 5000) will open the lock. Incorrect entries sound the alarm and disable the keyboard for up to 3 mins. Kit includes 12 way keypad, and operates from 9 to 15V (50uA) supply. Will drive relay or 701 150 lock mechanism.

**XK121**
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# TRACK FEEDBACK

## DISAPPOINTMENT

**Dear Sir**

'I was quite disappointed with part two of the 'Home Security Controller' of Oct 89 as I had expected some intelligent explanation of programming a microprocessor and on writing the software. Instead we were given advice to purchase an expensive manual. The table on page 52 is a mystery to me, so is the expression 'hex dump'.

May I also add that, although I am a professional electronic engineer I, like many other of my generation, never had any training in computers and software. My main reason for obtaining PE is a hope of finding articles dealing with this subject, and giving me some interesting and useful applications.

**E. du Puget, Oadby, Leics.**

*You have, of course, highlighted a problem that faces any broad-based magazine, that of satisfying the varying abilities of a diverse readership.*

*We try to provide a fair mix of projects of varying degrees of sophistication, some suiting early beginners, some for those with average experience, plus some which are best suited to readers who would classify themselves as advanced. The project you mention is one of those for the many readers who are experienced in computer-type projects, and who know how to program an eprom device.*

*With a more sophisticated project it is not right that we should cover all the very elementary information, such as eprom programming and the nature of hex codes, that is from time to time covered as general instructional articles - we would be guilty of extreme repetition. Readers must decide for themselves whether they are sufficiently experienced to tackle a particular project. If they do not have the experience, they have several choices: not to attempt the project; to do further research and experimentation; to be patient and wait for a more explicit tutorial article on the techniques required.*

*If you need more basic information on computers, read Owen Bishop's recent series of articles on Digital Electronics. We have also a couple of projects in the pipeline which are for eprom programmers and may be of interest to you. Photocopies of the PE Microfile article referred in the Home Security project are available at £1.00 (overseas 1.50) including post. Ed*

## RABBIT FEEDER

**Dear Ed**

For my GCSE in Technology I have to design and make a project and I want to make a rabbit feeder. I need a basic circuit with a timing device to tip a container of food into the rabbit hutch. Can you give me any ideas or a circuit?

**Stuart Sands, Chesterfield, Derbyshire.**

*I regret that I don't have a circuit to offer you, but you might find food for thought from some recent PE articles. In Ask PE of Nov and Dec 89 two timing circuits were described which might be useful. The output could be used to drive a relay, as for example in the circuit shown in the Teacher Locker of Oct 87. The relay could perhaps switch on a motor which would rotate the food hopper (at slow speed - you don't want to shoot the rabbit with ricochetting food pellets!)*

*Frequently I am asked to offer advice and even design circuits for those doing GCSE. It pains me to have to turn down the requests for in-depth help, but I honestly do not have enough hours in the day to oblige such pleadings. In any case, as I have said before, you will be partly judged in your exam on the thinking you have put into your project. In the long run you will be better off by not asking someone else to do your design for you. You will gain far more by trying out your own ideas. Even if they don't work, you will hopefully gain knowledge from reasoning out why they didn't work. One way you can benefit from reading PE, apart from reading the tutorial features, is to study the circuits of the simpler projects and see if they give you any ideas or hints, such as those I given above for keeping the poor rabbit from starvation! Ed*

**If you have any comments, criticisms or suggestions, write and let us know. We are interested in what you think and say.**

# HF RADIO

### Part Six
### by Mike Saunders

**In this last part we look at RF and IF stage design, filters and detectors.**

## CW TRANSMITTERS

In Morse transmission the carrier is switched on and off at a low power stage and one method of achieving this is by controlling the bias of a low power stage. The power supply of the final power amplifier or driver amplifier could also be switched on and off but this means switching high power.

The oscillator is not generally switched off and on since this causes chirp which are small variations in frequency. Keying affects the rise time of the carrier and a 10ms rise time should be aimed for.

A much slower time produces a soft sound which the ear finds difficult to copy and a fast rise time produces clicks which interfere with communication on the adjacent channels. If the stages after the keying stage are saturated, the carrier will be clipped and clicks will also be heard.

## AM TRANSMITTERS

Double sideband transmission can be achieved by several different methods:

i) controlling the gate bias voltage of a Class C fet in the final rf power amplifier.

ii) varying the final rf power amplifier's supply by means of transformer coupling.

iii) variation of the final rf amplifier by series control.

iv) low level modulation as discussed previously under cw.

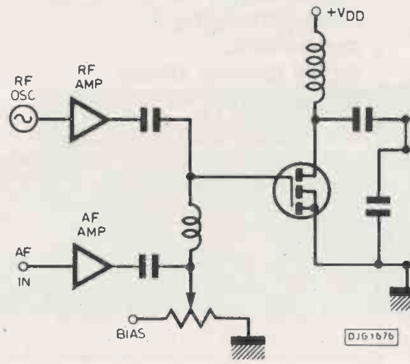


Fig 22. (left) AM by gate bias control.
Fig 23. (below) AM by transformer coupling.

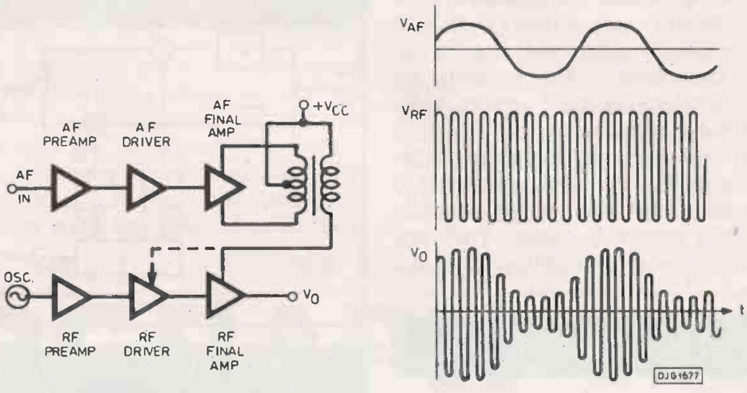


Fig. 22 illustrates am modulation by gate bias control. Varying the bias on the gate causes the amplitude of the output voltage to vary. The method is crude and produces a distortion of 5% to 10% but the circuitry is simple and therefore used in cheap transmitters. The distortion can be reduced by envelope feedback.

If a vmos fet is used the gate bias modulation is analagous to control grid modulation in a vacuum tube.

Fig. 23 illustrates am by means of transformer coupling.

## FM TRANSMITTERS

The phase locked loop modulation (Fig. 24) can be employed as a modulator or demodulator giving linear deviations up to ± 180 degrees.

Frequency modulation can be achieved directly by varying the oscillator frequency with the audio or indirectly by phase modulating the rf carrier by the integrated audio signal.

Direct fm can be obtained by pulling the frequency of a crystal oscillator by means of a voltage variable capacitor (vvc). The vvc is commonly known as a varactor diode, varicap or epicap. These are popular in mobile or portable transmitters.

The varactor operates on reverse bias with a capacitance given approximately by:

$$C = \frac{C1}{(-V_D)}$$

Where $V_D \leq -1$, and $C_1$ is the capacitance with $V_D = -1V$

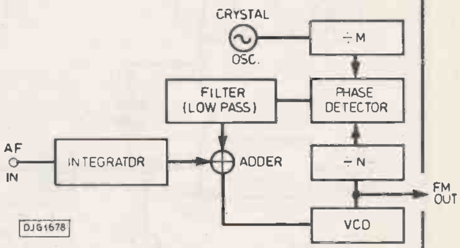
The parameters of the diode junction are engineered to provide the required relationship between the capacitance and voltage.

Typical diodes have N approximately 1/2 and Q of 100 to 500 with a capacitance variation of 3:1. Diodes with abrupt junctions have a Q of about 200 and 10:1 capacitance variation. Typical values of C1 are 100pf to 500pf and for VD , -2V to -10V. Varactors with linear frequency to voltage relationship also exist.

Indirect frequency modulation can be produced by integrating the audio and then comparing with a sawtooth. This is more complex than other fm methods but the quality is good and is used in broadcast transmitters.

The method is similar to that used in pulse width modulation. An oscillator of double the frequency of the output required drives a sawtooth generator, Fig. 25. The integrated audio is applied to the + input of the comparator and the sawtooth to the - input.

Fig 24. PLL modulator.



For simplicity the positive and negative peaks of the sawtooth are assumed to be equal.

This results in a high output when the audio is greater than the sawtooth voltage. The output of the comparator is applied to a multivibrator which switches at each falling edge and the output of the multivibrator is a rectangular pulse whose phase is proportionate to the instantaneous value of the audio voltage.

Such modulators are available in ic form for operation up to a few MHz. The linearity of the sawtooth determines the linearity of the modulator. The maximum deviation of 180 degrees is not usually achieved because of switching delays and fall time.

Frequency modulated feedback (fmfb) and automatic frequency control (afc) can be used to improve the linearity and stability of frequency modulators. The methods are similar to feedback in good quality audio amplifiers and available as ics.

The circuits detect the frequency of the oscillator or modulator output, compare it to the audio input or detector output reference and generate a correction voltage. Fmfb acts at the audio frequency rate while afc acts at a lower rate.

## SSB TRANSMITTERS

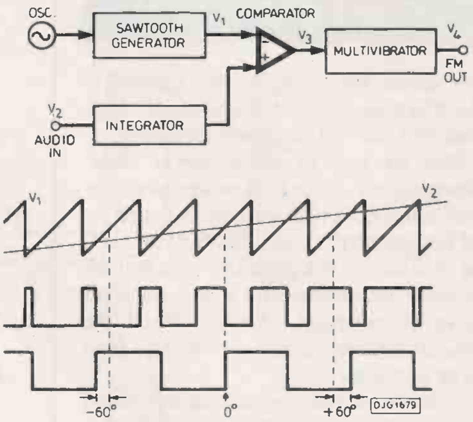
Single sideband transmitters are used in aircraft, marine, military and amateur communication. Here the communication spectrum could occupy slots over several octaves whereas that for cw, am and fm is confined to discrete bands.

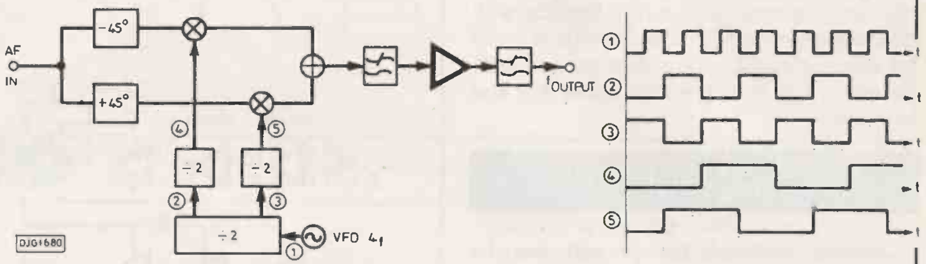
The modulating signal is usually speech and therefore speech compression is usually employed. Transmitters and receivers may be classed as direct conversion, multiple conversion or broadband. In multiple conversion, several stages of frequency translation are employed.

## DIRECT CONVERSION

Direct conversion is used in low cost transmitters when a single band of frequencies needs to be transmitted. Fig. 26 shows one possible configuration.

**Fig 25. (right) FM modulator using a comparator.**
**Fig 26 (below). Direct conversion.**





## DISCRETE BAND MULTIPLE CONVERSION

HF communication in the range 1.6MHz to 30MHz using the ionosphere is subject to rapid fading depending on the frequency used, condition of ionosphere, time of day, latitude, season of year, etc. Therefore several bands within the spectrum are allocated. In order to switch bands the stages need to be ganged together, (Fig. 27) so that they may be switched simultaneously.

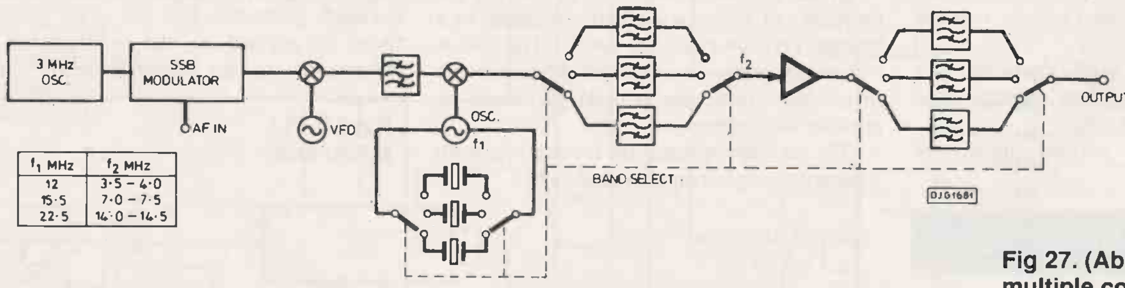
Discrete band frequency translation started during the vacuum tube era. At 3.5MHz and during daytime one would expect a range of 300km, and 1000km to 2000km at 14MHz on the first hop.

In Fig. 27, the variable frequency oscillator 5MHz to 5.5MHz translates the 3MHz ssb input into the 8MHz to 8.5MHz band. A crystal oscillator then translates this band into a discrete 0.5MHz band depending on the crystal and bandpass filter selected. Fig. 27 shows some possibilities but the harmonics require careful investigation. For instance the third harmonic of the vfo is in the range 15MHz to 16.5MHz.

When mixed with the crystal oscillator output of 12MHz, the output is in the 3MHz to 4.5MHz band. Therefore if the third harmonic of the vfo reaches the second mixer when operating in the 3.5MHz to 4.0MHz range, spurious signals will be heard.

## BROADBAND CONVERSION

Newer transmitters and receivers use broadband conversion since it is beneficial to standardise a design. Also military applications require transmitters to operate anywhere in the hf band.



| f1 MHz | f2 MHz |
|---|---|
| 12 | 3·5 – 4·0 |
| 15·5 | 7·0 – 7·5 |
| 22·5 | 14·0 – 14·5 |

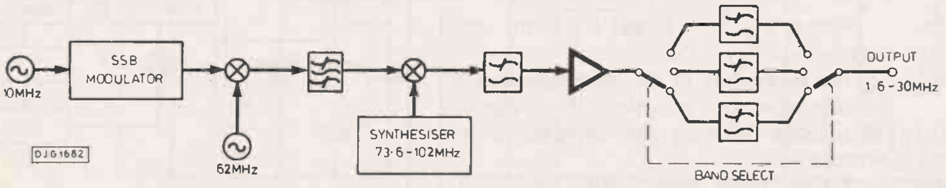


**Fig 27. (Above) Discrete and multiple conversion**
**Fig 28. (Left) Broadband conversion.**

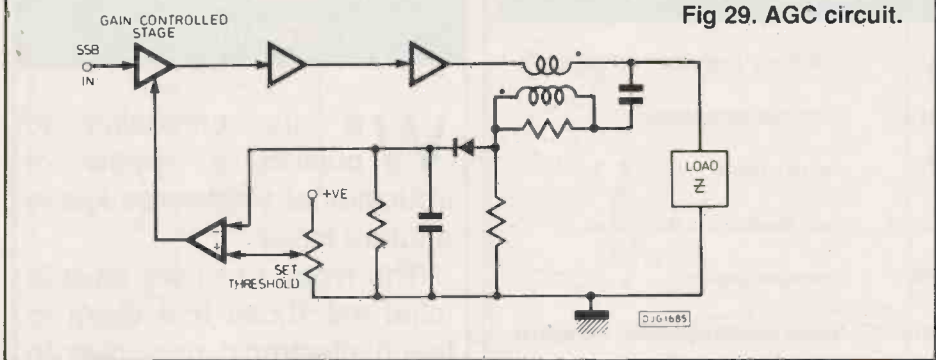


Fig 29. AGC circuit.

Fig. 28 shows a block diagram for broadband conversion. The ssb at 10MHz is mixed with 62MHz from an oscillator to produce a 72MHz intermediate frequency (IF). A frequency synthesiser with a range of 73.6MHz to 102MHz then translates the 72MHz so that it lies within the broadband output 1.6MHz to 30MHz, of the transmitter.

The advantages of the broadband method over the discrete method is that sideband inversion is not encountered with changing frequency since the IF is above the output frequency. Also the image rejection is good. For instance the unwanted product of the IF and frequency synthesiser is above 145MHz (72 + 73.6) and therefore above the transmitter output range.

Having a high centre frequency (88MHz) for the frequency synthesiser simplifies its design since the changes (± 14.2MHz) for tuning over its range is only 16%.

## AMPLIFIER CHAINS

A typical mixer output is 1mW and this is boosted to the required output level by a chain of linear amplifiers. These amplifiers may be Class A RF amplifiers of 100mW output or class B of 1W and higher.

## AUTOMATIC GAIN CONTROL

Automatic gain control (agc) is used in both transmitters and receivers. It guards against over drive as well as against under drive. For instance speech through a microphone is of variable strength and a whisper would drive the stages too weakly. On the other hand, driving the final amplifiers of a transmitter too hard causes distortion.

Agc circuitry in transmitters and receivers are of similar configuration. In Fig. 29, the rf output is fed to an envelope detector and the overall gain depends on the peak signal rather than the average signal. This is possible because the envelop detector has a fast attack (less than 10ms) and slow decay (0.1s to 1s).

The feedback for controlling gain is applied to a low power stage. That stage may be a dual gate fet, pin diode or dedicated ic. The current though a positive-intrinsic-negative (pin) diode determines the conductivity and the stored charge.

A pin diode acts like any pn junction diode at low frequencies but at high frequencies, only the dc controls the conductance of the pin diode. The pin then becomes a current controlled device with resistance:

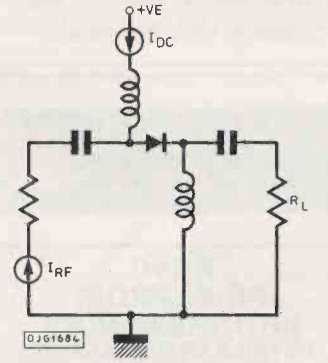
$$R = \frac{K}{0.88}$$

where K is within 10 to 30

I is 10μA to 1mA

R is 15ohms to 1000ohms

Fig. 30 shows how a pin diode is used for gain control. The rf signal flows through the capacitors, diode and load but the dc flows only through the diode and chokes.



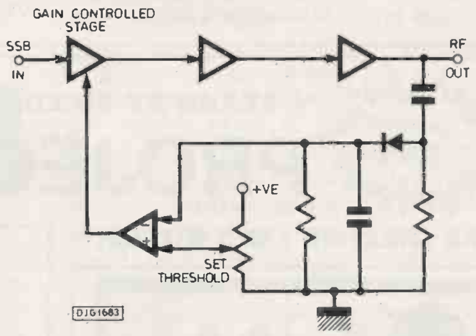


Fig 30 (above). PIN circuit for gain control.
Fig 31 (right). VSWR detector.

## VSWR PROTECTION

The agc is designed so that a power amplifier delivers the required power into a specific load impedance. If this impedance varies, the performance degrades, or worse still, the transistors are stressed. The antenna input impedance can vary for instance when a mobile transceiver travels under a bridge.

If the output voltage drops because the load resistance has dropped then the agc drives the final amplifier harder in order to restore the output. Reactive loads in particular increase heat dissipation in transistors and shorten their lives.

Low impedance loads can be guarded against by a current limiter in the power supply of the final amplifier but good protection requires slightly more complex circuits.

Transmission line theory uses the term voltage standing wave ratio (vswr) to indicate how well a load is matched to a resistive source. Formulae exist for converting an impedance Z into a vswr S and vise vera. At one extreme S equals infinity for a complete mismatch and S = 1 for a perfect match.

Proper vswr detectors employ loosely coupled transmission lines to drive signals which are proportionate to the forward as well as reflected power. The circuit in Fig. 31 is not strictly a vswr detector since the V1 is not the vswr S connected with impedance Z. Nevertheless, the circuit is commonly called a vswr detector.

The agc circuit of Fig. 29 and the vswr detector of Fig. 31 have similarities. Both may be incorporated in the same loop by reducing the output of the transformer so that when the load is its nominal value $R_0$, the component of the peak output voltage appears in V1.

## SUMMARY

After some initial definitions of sensitivity, selectivity, noise figure, IF and image rejection, the design requirements of the RF and IF stages were investigated. The rf stage was required to have good stability and selectivity and linear amplification to prevent imd and cmd.

A low IF was selected in the days of the vacuum tube and this does not assist image rejection. Nevertheless, cheap, portable am receivers are possible because broadcast transmitters are located in every city. Although transformer filters are good, the requirement for small, light filters has led to the development of ceramic, crystal and saw filters.

The most popular detector is the diode detector because it is cheap and simple and for stabilising the gain, agc is applied to ten RF and IF stages. It was seen how squelch was combined with agc to remove background noise in shared channels.

Although fm receivers are not affected by amplitude distortion, they are affected by phase distortion and the IF stage must have a linear transfer function. For each type of detector and modulator index, there is a threshold snr and one can trade bandwidth for snr. Fig. 11 (last month) shows how the input and output snr can be traded against the threshold. Capture and quieting are the benefits of an fm system.

The earlier Foster-Seeley detector was replaced by the ratio detector and coincidence detector. Stereo fm broadcast involves the transmission of a (L + R) and (L - R) signal modulating a 38kHz subcarrier. A 19kHz pilot is transmitted instead of the subcarrier to relax the filter requirements. To guard against attenuation during propagation, the frequencies above 2122Hz are pre-emphasised by a differentiator before transmission and de-emphasised by an integrator at the receiver.

In cw transmitters, a low power stage is usually keyed and a carrier rise time of 10ms is about right. For am transmission there are many methods of achieving dsb operation.

In fm transmission, the use of a varicap in a pll was illustrated. For better quality fm, indirect modulation can be used by integrating the audio and then comparing with sawtooth. Fmfb and afc may be used to improve the linearity and stability.

Unlike am and fm, ssb transmitters are assigned several slots over the radio spectrum to overcome atmospheric fading. The conversion may be direct, multiple or broadband. Vswr protection is necessary for the protection of the transistors in a mobile transmitter and both vswr protection and agc can be combined in the same circuit.

Dedicated land lines dominate telephony communications but for broadcasting and mobile and marine communications, hf radio remains a viable option in spite of atmospheric fading.

## GLOSSARY

| | |
|---|---|
| AFC | automatic frequency control |
| AGC | automatic gain control |
| CB | citizen's band |
| CMD | cross modulation distortion |
| CW | continuous wave |
| DSB/SC | double sideband/suppressed carrier |
| FMFB | frequency modulated feedback |
| IMD | intermodulation distortion |
| LSB | lower sideband |
| PLL | phase locked loop |
| SAW | surface acoustic wave |
| SNR | signal to noise ratio |
| SSB | single sideband |
| USB | upper sideband |
| VCO | voltage controlled oscillator |
| VSWR | voltage standing wave ratio |
| VVR | voltage variable capacitor |

PE

## TUTORIAL KITS REVIEW

We are proposing to publish a review of educational electronics kits in a future issue.

The types of kit we have in mind are those that claim to teach electronic principles to novices and are frequently available through high-street stores. This review will not cover the types of kit offered for the constructional projects published in PE and other magazines.

If you have any information or comments on educational kits, we would be pleased to hear from you. Manufacturers' and suppliers' names and address would also be gratefully received.

PE

## No. 1 LIST BAKERS DOZEN PACKS

All packs are £1 each, if you order 12 then you are entitled to another free. Please state which one you want. Note the figure on the extreme left of the pack ref number and the next figure is the quantity of items in the pack, finally a short description.

| | | |
|---|---|---|
| BD2 | 5 | 13A spurs provide a fused outlet to a ring main where devices such as a clock must not be switched off. |
| BD7 | 4 | In flex switches with neon on/off lights, saves leaving things switched on. |
| BD9 | 2 | 6V 1A mains transformers upright mounting with fixing clamps. |
| BD11 | 1 | 6½in speaker cabinet ideal for extensions, takes our speaker. Ref BD137. |
| BD13 | 12 | 30 watt reed switches, it's surprising what you can make with these – burglar alarms, secret switches, relay, etc., etc. |
| BD22 | 2 | 25 watt loud speaker two unit cross-overs. |
| BD29 | 1 | B.O.A.C. stereo unit is wonderful breakdown value. |
| BD30 | 2 | Nicad constant current chargers adapt to charge almost any nicad battery. |
| BD32 | 2 | Humidity switches, as the air becomes damper the membrane stretches and operates a microswitch. |
| BD42 | 5 | 13A rocker switch three tags so on/off, or change over with centre off. |
| BD45 | 1 | 24hr time switch, ex-Electricity Board, automatically adjust for lengthening and shortening day original cost £40 each. |
| BD49 | 10 | Neon valves, with series resistor, these make good night lights. |
| BD56 | 1 | Mini uniselector, one use is for an electric jigsaw puzzle, we give circuit diagram for this. One pulse into motor, moves switch through one pole. |
| BD59 | 2 | Flat solenoids – you could make your multi-tester read AC amps with this. |
| BD67 | 1 | Suck or blow operated pressure switch, or it can be operated by any low pressure variation such as water level in water tanks. |
| BD91 | 1 | Mains operated motors with gearbox. Final speed 16 rpm, 2 watt rated. |
| BD103A | 1 | 6V 750mA power supply, nicely cased with mains input and 6V output leads. |
| BD120 | 2 | Stripper boards, each contains a 400V 2A bridge rectifier and 14 other diodes and rectifiers as well as dozens of condensers, etc. |
| BD128 | 10 | Very fine drills for pcb boards etc. Normal cost about 80p each. |
| BD132 | 2 | Plastic boxes approx 3in cube with square hole through top so ideal for interrupted beam switch. |
| BD134 | 10 | Motors for model aeroplanes, spin to start so needs no switch. |
| BD139 | 6 | Microphone inserts – magnetic 400 ohm also act as speakers. |
| BD148 | 4 | Reed relay kits, you get 16 reed switches and 4 coil sets with notes on making c/o relays and other gadgets. |
| BD149 | 6 | Safety cover for 13A sockets – prevent those inquisitive little fingers getting nasty shocks. |
| BD180 | 6 | Neon Indicators in panel mounting holders with lens. |
| BD193 | 6 | 5 amp 3 pin flush mounting sockets make a low cost disco panel. Need cable clips |
| BD196 | 1 | in flex simmerstat – keeps your soldering iron etc. always at the ready. |
| BD199 | 1 | Mains solenoid, very powerful, has 1in pull or could push if modified. |
| BD201 | 8 | Keyboard switches – made for computers but have many other applications. |
| BD211 | 1 | Electric clock, mains operated, put this in a box and you need never be late. |
| BD221 | 5 | 12V alarms, make a noise about as loud as a car horn. Slightly soiled but OK. |
| BD242 | 2 | 6in ×4in speakers, 4 ohm made from Radiomobile so very good quality. |
| BD252 | 1 | Panostat, controls output of boiling ring from simmer to boil. |
| BD259 | 50 | Leads with push-onb ¼in tags – a must for hook-ups – mains connections etc. |
| BD263 | 2 | Oblong push switches for bell or chimes, these can mains up to 5 amps so could be foot switch if fitted into pattress. |
| BD268 | 1 | Mini 1 watt amp for record player. Will also change speed of record player motor. |
| BD283 | 3 | Mild steel boxes approx 3in × 3in × 1in deep – standard electrical. |
| BD293 | 50 | Mixed silicon diodes. |
| BD305 | 1 | Tubular dynamic mic with optional table rest. |
| BD400 | 4 | Books, useful for beginners, describes amplifiers, equipment and kit sets. |
| BD653 | 2 | Miniature driver transformers. Ref. LT44.<br>20k to 1k centre tapped. |
| BD553a | 2 | 3.5V relays each with 2 pairs changeover contacts. |

There are over 1,000 items in our Bakers Dozen List. If you want a complete copy, please request one when ordering.

**EQUIPMENT WALL MOUNT** It is a multi-adjustable metal bracket tht could be used for mounting flood light,loud speakers, TV camera, even a tan and on almost any sort of wall or ceiling even between wall and ceiling. The main fixing brackets rotate such that an inward or an outward corner can be accommodated. Front panel also tilts upwards or downwards to a reasonable angle and can be easily removed separately for wiring. A very useful bracket. Regular price wuld be around £6 each. Our price only £3. Our ref 3P72. Or 2 for £5. Our ref 5P152.

**EXTRA SPECIAL CROC CLIPS** Medium size, just right for most hook-ups. Normally sell for around 10p to 15p each. These are insulated and have a length of wire connected to them but this is very easy to snip off if you do not need it. 20 for £1. Our ref BD117A.

**COPPER CLAD PANEL** for making PCB. Size approx 12in long x 8½in wide. Double-sided on fibreglass middle which is quite thick (about 1/16in) so this would support quite heavy components and could even form a chassis to hold a mains transformer, etc. Price £1 each. Our ref BD683.

### POWERFUL IONISER

Generates approx 10 times more IONS than the ETI and similar circuits. Will refresh your home, office, workroom, etc. Makes you feel better and work harder – a complete mains operated kit, case included. £12.50 plus £2 postage. Our ref 12P5/1.

**REAL POWER AMPLIFIER** for your car, it has 150 watts output. Frequency response 20hz and signal to noise ratio better than 60d/b. Has built in short circuit protection and adjustable level to suit your existing car stereo, so needs no pre-amp. Works into speakers. Ref 30P7 described below. A real bargain at only £57.50. Order ref. 57P1.

**REAL POWER CAR SPEAKERS** Stereo pari output 100w eaach. 4-Ohm Impedence and consisting of 6½" woofer, 2" mid range and 1" tweeter. Each set in a compact purpose built shelf mounting unit. Ideal to work with the amplifier described above. Price per pair £29.96. Order ref. 30P7.

**STEREO CAR SPEAKERS** Not quit so powerful – 70w per channel. 3" woofer, 2" mid range and 1" tweeter. Again, in a super purpose built shelf mounting unit. Price per pair £27.95. Order ref. 28P1.

**ELECTRONIC SPACESHIP** Sound and impact controlled, responds to claps and shouts and reverses when it hits anything. Kit with really detailed instructions. Ideal present for budding young electrician. A youngster should be able to assemble but you may have to help with the soldering of the components on the pcb. Complete kit £8. Our ref 8P30.

**12" HIGH RESOLUTION MONITOR** Black and white screen, beautifully cased for free standing, needs only a 12v 1.5amp supply. Technical data is on its way but we understand these are TTL input. Brand new in maker's cartons. Price £25.00 plus £5 insured delivery. Order ref. 25P10.

**14" COLOUR MONITOR** made by the American Display Tek company. Uses high resolution tube made by the famous Japanese Toshiba company. Beautifully made unit intended for console mounting, but top and sides adequately covered by plated metal panels. Full technical spec. on its way to us. We have a limited number of these. All brand new still in maker's cartons. Price £89 each plus £6 insured carriage. Order ref. 89P/1.

**BUSH RADIO MIDI SPEAKERS** Stereo pair, BASS reflex system, using a full range 4in driver of 4ohms impedance. Mounted in very nicely made black fronted walnut finish cabinets. Cabinet size approx 8½in wide, 14in high and 3½in deep. Fitted with a good length of speaker flex and terminating with a normal audio plug. Price £5 the pair plus £1 post. Our ref 5P141.

**3½ FLOPPY DISC DRIVE** – We still have two models in stock. Single sided 80 track by Chinon. This is in the manufacturers metal case with leads and ICD connectors. Prive £40 reference 40P1. Also a double sided 80 track. This is uncased. Price £59.50 reference 60P2. Both are brand new. Insured delivery £3 on each or both.

### ATARI 65XE COMPUTER

At 64k this is most powerful and suitable for home and business. Brand new, complete with PSU, TV lead, owner's manual and six games. Can be yours for only £45 plus £3 insured delivery.

**REMOTE CONTROL FOR YOUR 65XE COMPUTER.** with this outfit you can be as much as 20 feet away as you will have a joystick that can transmit and a receiver to plug into and operate your computer and TV. This is also just right if you want to use it with a big screen TV. The joystick has two fire buttons and is of a really superior quality, with four suction cups for additional contorl and one handed play. Price £15 for the radio controlled pair. Our ref 15P27.

**65XE COMPENDIUM** Contains: 65XE Computer, its data recorder XC12 and its joystick, with ten games for £62.50 plus £4 insured deliver.

**ASTEC PSU** Mains operated switch mode, so very compact. Outputs: +12v 2.5A, +5v 6A, ± 5v .5A, ± 12v .5A. Size: 7¼ long × 4⅜in wide × 2¾in high. Cased ready for use. Brand new. Normal price £30+, our price only £12.95. Our ref 13P2.

**VERY POWERFUL 12 VOLT MOTORS.** ⅓rd Horsepower. Made to drive the Sinclair C5 electric car but adaptable to power a go-kart, a mower, a rail car, model railway, etc. Brand new. Price £20 plus £2 postage. Our ref 20P22.

### PHILIPS LASER

This is helium-neon and has a power rating of 2mW. Completely safe as long as you do not look directly into the beam when eye damage could result. Brand new, full spec. £30 plus £3 insured delivery. Mains operated power supply for this tube gives 1kv striking and 1.25kv at 5mA running. Complete kit with case £15. Ditto for 12v battery. Also £15. Our ref 15P22.

**ORGAN MASTER** Is there a three octave musical keyboard. It is beautifully made, has full size (piano size) keys, has gold plated contacts and is complete with ribbon cable and edge connector. Can be used with many computers. We can supply information sheet. Brand new, only £15 plus £3 postage. Our ref 15P15.

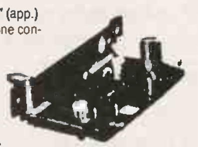
**FULL RANGE OF COMPONENTS** at very keen prices are available from our associate company SCS COMPONENTS. You may already have their catalogue, if not request one and we will send it FOC with your goods.

**FULL RANGE OF COMPONENTS** at very keen prices are available from our associate company SCS COMPONENTS. You may already have their catalogue, if not request one and we will send it FOC wity your goods.

**HIGH RESOLUTION MONITOR.** In black and white, used Philips tube M24/305W. Made up in a lacquered frame and has open sides. Made for use with OPD computer but suitable for most others. 5 and new. £16 plus £5 post. Our rel 16P1.

**12 VOLT BRUSHLESS FAN.** Japanese made. The popular square shape 14½ x 4½ x 17in). The electronically run fuse not only consume very little current but also they do not cause interference as the brush type motors do. Ideal for cooling computers, etc. or for a caravan. £8 each. Our ref 8P28.

**MINI MONO AMP** on p.c.b. size 4" × 2" (app.) Fitted volume control and a hole for a tone control should you require it. The amplifier has three transistors and we estimate the output to be 3W rms. More technical data will be included with the amp. Brand new, perfect condition, offered at the very low price of **£1.15 each, or 13 for £12.00.**



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## POPULAR ITEMS
## MANY NEW THIS MONTH

**SUB-MIN SWITCHES** Not much bigger than a plastic transistor but double pole. PCB mounting. Three for £1 Our ref 8D688

**CARTRIDGED** for the Double Microdrive. Price 4 for £5. Our ref 5P146.

**NICAD CHARGER UNIT** Metal pronged, plastic case contains mains transformer and rectifiers with output lead and plug – made to charge two cells but no doubt adaptable or wonderful spares value. ONly 50p each, two for £1. Our ref. DB386

**EDGEWISE PANEL METER.** If you are short of panel space then this may beh answer. It has a FSO of 100uA and a nice full vision scale. It fits through a hole approx. 1¼in x ½in. Another feature is that it has an indicator lamp behind the scale which you could light up. It would then serve as an on/off indicator. Price £1. Our ref BD700.

**AA CELLS.** Probably the most popular of the rechargeable NICAD types. 4 for £4. Our ref 4P44.

**COMPUTER SPECIAL** The Porex 16meg Byte tape streamer. These are brand new and really an exceptional bargain. A few only so hurry. Only £15. Our ref 15P29.

**20 WATT 4OHM SPEAKERS** With built-in tweeter. Really well made unit which has the power and the quality for hi-fi reproduction. 6¼in diameter. Price £5. Our ref 5P155. It is heavy so please add £1 to cover postage if not collecting.

**MINI RADIO MODULE** only about 2in square with ferrite aerial and solid dai tuner with its own knob. It is a superhat and it operates from PP3 battery and would drive a crystal headphone direct but be better with our mini mono amp. Price £1. Our ref BD716

**BULGIN MAINS PLUG AND SOCKET** The old faithful 3 pin screw terminals. The socket mounts through a 1½in hole and the mains is brought in by the insulated plug. Used to be quite expensive but yo can have 2 pairs for £1 or 4 or either plug or socket for £1. You could make yourself a neat and compact bench panel with these. Our ref BD715 or BD715P.

**MICROPHONE** If you want a low cost microphone then just arrived we have a very small hand-held dynamic mic with on/off switch in the handle. Its lead terminates with one 3.5 plug and the other a 2.5 plug for remote control. Price only £1. Our ref BD711

**EXTENSION CABLE WITH A DIFFERENCE** It is flat on one side making it easy to fi and to look tidy. It is 4 core so suitable for telephone, bell, burglar alarms, etc. 50 yard coil for £5. Our ref 5P153.

**MOSFETS FOR POWER AMPLIFIERS AND HIGH CURRENT DEVICES** 140v 100w pair made by the famous Hitachi Company. Reference 25K413 and its compliment 25J118. Only £4 the pair. Our ref 4P42.

**BATTERY OPERATED TRAVEL MECHANISM** On a plastic panel measuring approx 9in × 3½in. Is driven by a reversible 12v battery motor, fitted with pulley and belt which rotates a threaded rod and causes a platform to travel backwards and forwards through a distance of approx 5in. Price £5. Our ref 5P140.

**MAINS OPERATED WATER VALVE** with hose connection for inlet and outlet suitable for low pressure. Auto plant watering, etc. Only £1 each. Our ref BD370.

**20 VOLT 4 AMP MAINS TRANSFORMER** Upright mounting with fixing feet. Price £3. Our ref 3P59.

**15OHM PM SPEAKERS** Approx 7in × 4in, 5 watts. Offered at a very low price so you can use two in parallel to give you 10 watts at 8 ohms. £1 for the two. Our ref BD684.

**EHT TRANSFORMER** 4kv 2mA Ex-unused equipment. £5. Our ref 5P139.

**4 CORE TINSEL COPPER LEAD** As fitted to telephones, terminating with flat BT plug. 2 for £1. Our ref BD639.

**EHT TRANSFORMER** 8kv 3mA. £10. Our ref 10P56.

**VERY USEFUL MAGNETS** Flat, about 1in long, ½in wide and ¼in thick. Very powerful. 6 for £1. Our ref BD274(a).

**ACORN COMPUTER DATA RECORDER REF ALF03** Made for the Electron or BBC computers but suitable for most others. Complete with mains adaptor, leads and handbook. £10.00. £2 special packing. Ref 10P44.

**SOLAR CELLS** Will give a good current (depending on size) from sunlight or bright daylight. Module A gives 100mA. Price £1. Our ref BD631. Module C gives 400mA. Price £2. Our ref 2P199. Module D gives 700mA. Price £3. Our ref 3P42.

**SOLAR POWERED NI-CAD CHARGER** 4 Ni-Cad batteries AA (HP7) charged in eight hours or two in only 4 hours. It is a complete, boxed ready to use unit. Price £6. Our ref. 6P3.

**METAL PROJECT BOX** Ideal size for battery charger, power supply etc,; sprayed grey, size 8in x 4¼in high, ends are louvred for ventilation other sides are flat and undrilled. Order Ref. 2P191. Price £1.

**CAPACITOR BARGAIN** – axial ended, 4700µF at 25V. Jap made, normally 50p each, you get 4 for £1. Our ref. 613.

**SINGLE SCREENED FLEX** 7.02 copper conductors, pvs insulated then with cooper screen, finally outer insulation. In fact quite normal screened flex. 10m fo £1. Our ref DB668.

**3-CORE FLEX BARGAIN No. 1** – Core size 1.25mm so suitable for long extension leads carrying up to 13 amps, or short leads up to 10 amps. 15mm for £2. Ref. 2P190.

**3-CORE FLEX BARGAIN No. 2** – Core size 1.25mm so suitable for long extension leads carrying up to 13 amps, or short leads up to 25A. 10m for £2. Ref. 2P190.

**ALPHA-NUMERIC KEYBOARD** – This keyboard has 73 keys giving trouble free life and no contact bounce. The keys are arranged in two number pad, board size is approx. 13" x 4" – brand new but offered at only a fraction of its cost, namely £3 plus £1 post. Ref. 3P27.

**⅛TH HORSEPOWER 12 VOLT MOTOR** Made by Smiths, the body length of this is approximately 3in, the diameter 3in and the spindle 5/16th of an inch diameter. It has a centre flange for fixing or can be fixed from the end by means of 2 nuts. A very powerful little motor which revs at 3,000 rpm. We have a large quantity of them so if you have any projects in mind then you could rely on supplies for at least two years. Price £6. Our ref 6P1, discount for quantities of 10 or more.

**SUM-MIN TOGGLE SWITCH** Body size 8mm x 4mm x 7mm SBDT with chrome dolly fixing nuts. 4 for £1. Our ref BD649.

# RESISTORS IN PARALLEL

## Stuck for the odd component value? These tables from Joe Chamberlain will help!

The four tables show the resistor values obtainable when two E24 range resistors are connected in parallel.

The left hand column in each table lists the E24 resistor range from 10 ohms up to 91 ohms and the top row shows the same E24 range from 10 ohms (Table 1) to 910 ohms (Table 4).

The tables can be used in several different ways:

To determine the resistor value which results from connecting components in parallel, locate one resistor value in the left hand column and the other in the top row. Now run your finger to where the row and column intersect and read the value indicated. For example, to find the result of connecting 68 ohms in parallel with 82 ohms, take 68 ohms in the left hand column and 82 ohms in the top row (Table 2), which intersect at a value of 37.17 ohms.

## OUT OF RANGE

Now suppose that the resistors are outside the ranges shown, say 680 ohms and 1100 ohms. It takes no great knowledge of mathematics to establish that 680 is 10 times 68. Therefore multiply *both* the left hand and top values by a factor of 10. You must remember to multiply both scales. Then look at the 68 (x10) row aned the 110 (x10) column which intersect at 42.02 ohms and multiply this answer by the same x10 factor to give 420.2 ohms as the answer.

## TOLERANCE

Two important things have to be stressed at this point. Firstly, although the results are quoted to two decimal places the actual value which results will depend on the accuracy of the two resistors used. If for example we take the case of 10 ohms in parallel with 11 ohms (Table 1), the chart shows a resulting value of 5.24 ohms. This will only be true if both resistors used had a 1 per cent tolerance in the first place. However if you consider 10 ohms in parallel with say 100 ohms then a change of 10 per cent in the nominal value of the 100 ohm resistor will only result in slightly less than 1 per cent change in the final value.

## SHUNTING

This example leads to a second use of the tables which is to determine the effect of shunting one component with a range of other (usually larger) values. In the above example, shunting 10 ohms with 91, 100, 110 ohms gives values of 9.01, 9.09, and 9.17 ohms respectively. This technique is of considerable value in determining practical effects of temperature compensating resistors or thermistors.

## NON-STANDARD

A third and probably the most important application of the tables is in deriving a non-standard resistor value from a range of standard values. Take a couple of practical examples - how can a resistor of value 31.05 ohms be constructed? Scan the tables to find the nearest printed value, in this case giving at least three options:

| RES 1 | 10 | 11 | 12 | 13 | 15 | 16 | 18 | 20 | 22 | 24 | 27 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RES 2 | PRODUCT | | | | | | | | | | | |
| 10.00 | 5.00 | 5.24 | 5.45 | 5.65 | 6.00 | 6.15 | 6.43 | 6.67 | 6.87 | 7.06 | 7.30 | 7.50 |
| 11.00 | 5.24 | 5.50 | 5.74 | 5.96 | 6.35 | 6.52 | 6.83 | 7.10 | 7.33 | 7.54 | 7.82 | 8.05 |
| 12.00 | 5.45 | 5.74 | 6.00 | 6.24 | 6.67 | 6.86 | 7.20 | 7.50 | 7.76 | 8.00 | 8.31 | 8.57 |
| 13.00 | 5.65 | 5.96 | 6.24 | 6.50 | 6.96 | 7.17 | 7.55 | 7.88 | 8.17 | 8.43 | 8.77 | 9.07 |
| 15.00 | 6.00 | 6.35 | 6.67 | 6.96 | 7.50 | 7.74 | 8.18 | 8.57 | 8.92 | 9.23 | 9.64 | 10.00 |
| 16.00 | 6.15 | 6.52 | 6.86 | 7.17 | 7.74 | 8.00 | 8.47 | 8.89 | 9.26 | 9.60 | 10.05 | 10.43 |
| 18.00 | 6.43 | 6.83 | 7.20 | 7.55 | 8.18 | 8.47 | 9.00 | 9.47 | 9.90 | 10.29 | 10.80 | 11.25 |
| 20.00 | 6.67 | 7.10 | 7.50 | 7.88 | 8.57 | 8.89 | 9.47 | 10.00 | 10.48 | 10.91 | 11.49 | 12.00 |
| 22.00 | 6.87 | 7.33 | 7.76 | 8.17 | 8.92 | 9.26 | 9.90 | 10.48 | 11.00 | 11.48 | 12.12 | 12.69 |
| 24.00 | 7.06 | 7.54 | 8.00 | 8.43 | 9.23 | 9.60 | 10.29 | 10.91 | 11.48 | 12.00 | 12.71 | 13.33 |
| 27.00 | 7.30 | 7.82 | 8.31 | 8.77 | 9.64 | 10.05 | 10.80 | 11.49 | 12.12 | 12.71 | 13.50 | 14.21 |
| 30.00 | 7.50 | 8.05 | 8.57 | 9.07 | 10.00 | 10.43 | 11.25 | 12.00 | 12.69 | 13.33 | 14.21 | 15.00 |
| 33.00 | 7.67 | 8.25 | 8.80 | 9.33 | 10.31 | 10.78 | 11.65 | 12.45 | 13.20 | 13.89 | 14.85 | 15.71 |
| 36.00 | 7.83 | 8.43 | 9.00 | 9.55 | 10.59 | 11.08 | 12.00 | 12.86 | 13.66 | 14.40 | 15.43 | 16.36 |
| 39.00 | 7.96 | 8.58 | 9.18 | 9.75 | 10.83 | 11.35 | 12.32 | 13.22 | 14.07 | 14.86 | 15.95 | 16.96 |
| 43.00 | 8.11 | 8.76 | 9.38 | 9.98 | 11.12 | 11.66 | 12.69 | 13.65 | 14.55 | 15.40 | 16.59 | 17.67 |
| 47.00 | 8.25 | 8.91 | 9.56 | 10.18 | 11.37 | 11.94 | 13.02 | 14.03 | 14.99 | 15.89 | 17.15 | 18.31 |
| 51.00 | 8.36 | 9.05 | 9.71 | 10.36 | 11.59 | 12.18 | 13.30 | 14.37 | 15.37 | 16.32 | 17.65 | 18.89 |
| 56.00 | 8.48 | 9.19 | 9.88 | 10.55 | 11.83 | 12.44 | 13.62 | 14.74 | 15.79 | 16.80 | 18.22 | 19.53 |
| 62.00 | 8.61 | 9.34 | 10.05 | 10.75 | 12.08 | 12.72 | 13.95 | 15.12 | 16.24 | 17.30 | 18.81 | 20.22 |
| 68.00 | 8.72 | 9.47 | 10.20 | 10.91 | 12.29 | 12.95 | 14.23 | 15.45 | 16.62 | 17.74 | 19.33 | 20.82 |
| 75.00 | 8.82 | 9.59 | 10.34 | 11.08 | 12.50 | 13.19 | 14.52 | 15.79 | 17.01 | 18.18 | 19.85 | 21.43 |
| 82.00 | 8.91 | 9.70 | 10.47 | 11.22 | 12.68 | 13.39 | 14.76 | 16.08 | 17.35 | 18.57 | 20.31 | 21.96 |
| 91.00 | 9.01 | 9.81 | 10.60 | 11.37 | 12.88 | 13.61 | 15.03 | 16.40 | 17.72 | 18.99 | 20.82 | 22.56 |

| RES 1 | 33 | 36 | 39 | 43 | 47 | 51 | 56 | 62 | 68 | 75 | 82 | 91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RES 2 | PRODUCT | | | | | | | | | | | |
| 10.00 | 7.67 | 7.83 | 7.96 | 8.11 | 8.25 | 8.36 | 8.48 | 8.61 | 8.72 | 8.82 | 8.91 | 9.01 |
| 11.00 | 8.25 | 8.43 | 8.58 | 8.76 | 8.91 | 9.05 | 9.19 | 9.34 | 9.47 | 9.59 | 9.70 | 9.81 |
| 12.00 | 8.80 | 9.00 | 9.18 | 9.38 | 9.56 | 9.71 | 9.88 | 10.05 | 10.20 | 10.34 | 10.47 | 10.60 |
| 13.00 | 9.33 | 9.55 | 9.75 | 9.98 | 10.18 | 10.36 | 10.55 | 10.75 | 10.91 | 11.08 | 11.22 | 11.37 |
| 15.00 | 10.31 | 10.59 | 10.83 | 11.12 | 11.37 | 11.59 | 11.83 | 12.08 | 12.29 | 12.50 | 12.68 | 12.88 |
| 16.00 | 10.78 | 11.08 | 11.35 | 11.66 | 11.94 | 12.18 | 12.44 | 12.72 | 12.95 | 13.19 | 13.39 | 13.61 |
| 18.00 | 11.65 | 12.00 | 12.32 | 12.69 | 13.02 | 13.30 | 13.62 | 13.95 | 14.23 | 14.52 | 14.76 | 15.03 |
| 20.00 | 12.45 | 12.86 | 13.22 | 13.65 | 14.03 | 14.37 | 14.74 | 15.12 | 15.45 | 15.79 | 16.08 | 16.40 |
| 22.00 | 13.20 | 13.66 | 14.07 | 14.55 | 14.99 | 15.37 | 15.79 | 16.24 | 16.62 | 17.01 | 17.35 | 17.72 |
| 24.00 | 13.89 | 14.40 | 14.86 | 15.40 | 15.89 | 16.32 | 16.80 | 17.30 | 17.74 | 18.18 | 18.57 | 18.99 |
| 27.00 | 14.85 | 15.43 | 15.95 | 16.59 | 17.15 | 17.65 | 18.22 | 18.61 | 19.33 | 19.85 | 20.31 | 20.82 |
| 30.00 | 15.71 | 16.36 | 16.96 | 17.67 | 18.31 | 18.89 | 19.53 | 20.22 | 20.82 | 21.43 | 21.96 | 22.56 |
| 33.00 | 16.50 | 17.22 | 17.87 | 18.67 | 19.39 | 20.04 | 20.76 | 21.54 | 22.22 | 22.92 | 23.53 | 24.22 |
| 36.00 | 17.22 | 18.00 | 18.72 | 19.59 | 20.39 | 21.10 | 21.91 | 22.78 | 23.54 | 24.32 | 25.02 | 25.80 |
| 39.00 | 17.87 | 18.72 | 19.50 | 20.45 | 21.31 | 22.10 | 22.99 | 23.94 | 24.79 | 25.66 | 26.43 | 27.30 |
| 43.00 | 18.67 | 19.59 | 20.45 | 21.50 | 22.46 | 23.33 | 24.32 | 25.39 | 26.34 | 27.33 | 28.21 | 29.20 |
| 47.00 | 19.39 | 20.39 | 21.31 | 22.46 | 23.50 | 24.46 | 25.55 | 26.73 | 27.79 | 28.89 | 29.88 | 30.99 |
| 51.00 | 20.04 | 21.10 | 22.10 | 23.33 | 24.46 | 25.50 | 26.69 | 27.98 | 29.14 | 30.36 | 31.44 | 32.68 |
| 56.00 | 20.76 | 21.91 | 22.99 | 24.32 | 25.55 | 26.69 | 28.00 | 29.42 | 30.71 | 32.06 | 33.28 | 34.67 |
| 62.00 | 21.54 | 22.78 | 23.94 | 25.39 | 26.73 | 27.98 | 29.42 | 31.00 | 32.43 | 33.94 | 35.31 | 36.88 |
| 68.00 | 22.22 | 23.54 | 24.79 | 26.34 | 27.79 | 29.14 | 30.71 | 32.43 | 34.00 | 35.66 | 37.17 | 38.92 |
| 75.00 | 22.92 | 24.32 | 25.66 | 27.33 | 28.89 | 30.36 | 32.06 | 33.94 | 35.66 | 37.50 | 39.17 | 41.11 |
| 82.00 | 23.53 | 25.02 | 26.43 | 28.21 | 29.88 | 31.44 | 33.28 | 35.31 | 37.17 | 39.17 | 41.00 | 43.13 |
| 91.00 | 24.22 | 25.80 | 27.30 | 29.20 | 30.99 | 32.68 | 34.67 | 36.88 | 38.92 | 41.11 | 43.13 | 45.50 |

**Tables 1 and 2: Range 10 to 91.**

| RES 1 | 100 | 110 | 120 | 130 | 150 | 160 | 180 | 200 | 220 | 240 | 270 | 300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RES 2 | PRODUCT | | | | | | | | | | | |
| 10.00 | 9.09 | 9.17 | 9.23 | 9.29 | 9.37 | 9.41 | 9.47 | 9.52 | 9.57 | 9.60 | 9.64 | 9.68 |
| 11.00 | 9.91 | 10.00 | 10.08 | 10.14 | 10.25 | 10.29 | 10.37 | 10.43 | 10.48 | 10.52 | 10.57 | 10.61 |
| 12.00 | 10.71 | 10.82 | 10.91 | 10.99 | 11.11 | 11.16 | 11.25 | 11.32 | 11.38 | 11.43 | 11.49 | 11.54 |
| 13.00 | 11.50 | 11.63 | 11.73 | 11.82 | 11.96 | 12.02 | 12.12 | 12.21 | 12.27 | 12.33 | 12.40 | 12.46 |
| 15.00 | 13.04 | 13.20 | 13.33 | 13.45 | 13.64 | 13.71 | 13.85 | 13.95 | 14.04 | 14.12 | 14.21 | 14.29 |
| 16.00 | 13.79 | 13.97 | 14.12 | 14.25 | 14.46 | 14.55 | 14.69 | 14.81 | 14.92 | 15.00 | 15.10 | 15.19 |
| 18.00 | 15.25 | 15.47 | 15.65 | 15.81 | 16.07 | 16.18 | 16.36 | 16.51 | 16.64 | 16.74 | 16.87 | 16.98 |
| 20.00 | 16.67 | 16.92 | 17.14 | 17.33 | 17.65 | 17.78 | 18.00 | 18.18 | 18.33 | 18.46 | 18.62 | 18.75 |
| 22.00 | 18.03 | 18.33 | 18.59 | 18.82 | 19.19 | 19.34 | 19.60 | 19.82 | 20.00 | 20.15 | 20.34 | 20.50 |
| 24.00 | 19.35 | 19.70 | 20.00 | 20.26 | 20.69 | 20.87 | 21.18 | 21.43 | 21.64 | 21.82 | 22.04 | 22.22 |
| 27.00 | 21.26 | 21.68 | 22.04 | 22.36 | 22.88 | 23.10 | 23.48 | 23.79 | 24.05 | 24.27 | 24.55 | 24.77 |
| 30.00 | 23.08 | 23.57 | 24.00 | 24.37 | 25.00 | 25.26 | 25.71 | 26.09 | 26.40 | 26.67 | 27.00 | 27.27 |
| 33.00 | 24.81 | 25.38 | 25.88 | 26.32 | 27.05 | 27.36 | 27.89 | 28.33 | 28.70 | 29.01 | 29.41 | 29.73 |
| 36.00 | 26.47 | 27.12 | 27.69 | 28.19 | 29.03 | 29.39 | 30.00 | 30.51 | 30.94 | 31.30 | 31.76 | 32.14 |
| 39.00 | 28.06 | 28.79 | 29.43 | 30.00 | 30.95 | 31.36 | 32.05 | 32.64 | 33.13 | 33.55 | 34.08 | 34.51 |
| 43.00 | 30.07 | 30.92 | 31.66 | 32.31 | 33.42 | 33.89 | 34.71 | 35.39 | 35.97 | 36.47 | 37.09 | 37.61 |
| 47.00 | 31.97 | 32.93 | 33.77 | 34.52 | 35.79 | 36.33 | 37.27 | 38.06 | 38.73 | 39.30 | 40.03 | 40.63 |
| 51.00 | 33.77 | 34.84 | 35.79 | 36.63 | 38.06 | 38.67 | 39.74 | 40.64 | 41.40 | 42.06 | 42.90 | 43.59 |
| 56.00 | 35.90 | 37.11 | 38.18 | 39.14 | 40.78 | 41.48 | 42.71 | 43.75 | 44.64 | 45.41 | 46.38 | 47.19 |
| 62.00 | 38.27 | 39.65 | 40.88 | 41.98 | 43.87 | 44.68 | 46.12 | 47.33 | 48.37 | 49.27 | 50.42 | 51.38 |
| 68.00 | 40.48 | 42.02 | 43.40 | 44.65 | 46.79 | 47.72 | 49.35 | 50.75 | 51.94 | 52.99 | 54.32 | 55.43 |
| 75.00 | 42.86 | 44.59 | 46.15 | 47.56 | 50.00 | 51.06 | 52.94 | 54.55 | 55.93 | 57.14 | 58.70 | 60.00 |
| 82.00 | 45.05 | 46.98 | 48.71 | 50.28 | 53.02 | 54.21 | 56.34 | 58.16 | 59.74 | 61.12 | 62.90 | 64.40 |
| 91.00 | 47.64 | 49.80 | 51.75 | 53.53 | 56.64 | 58.01 | 60.44 | 62.54 | 64.37 | 65.98 | 68.06 | 69.82 |

| RES 1 | 330 | 360 | 390 | 430 | 470 | 510 | 560 | 620 | 680 | 750 | 820 | 910 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RES 2 | PRODUCT | | | | | | | | | | | |
| 10.00 | 9.71 | 9.73 | 9.75 | 9.77 | 9.79 | 9.81 | 9.82 | 9.84 | 9.86 | 9.87 | 9.88 | 9.89 |
| 11.00 | 10.65 | 10.67 | 10.70 | 10.73 | 10.75 | 10.77 | 10.79 | 10.81 | 10.82 | 10.84 | 10.85 | 10.87 |
| 12.00 | 11.58 | 11.61 | 11.64 | 11.67 | 11.70 | 11.72 | 11.75 | 11.77 | 11.79 | 11.81 | 11.83 | 11.84 |
| 13.00 | 12.51 | 12.55 | 12.58 | 12.62 | 12.65 | 12.68 | 12.71 | 12.73 | 12.76 | 12.78 | 12.80 | 12.82 |
| 15.00 | 14.35 | 14.40 | 14.44 | 14.49 | 14.54 | 14.57 | 14.61 | 14.65 | 14.68 | 14.71 | 14.73 | 14.76 |
| 16.00 | 15.26 | 15.32 | 15.37 | 15.43 | 15.47 | 15.51 | 15.56 | 15.60 | 15.63 | 15.67 | 15.69 | 15.72 |
| 18.00 | 17.07 | 17.14 | 17.21 | 17.28 | 17.34 | 17.39 | 17.44 | 17.49 | 17.54 | 17.58 | 17.61 | 17.65 |
| 20.00 | 18.86 | 18.95 | 19.02 | 19.11 | 19.18 | 19.25 | 19.31 | 19.37 | 19.43 | 19.48 | 19.52 | 19.57 |
| 22.00 | 20.62 | 20.73 | 20.83 | 20.93 | 21.02 | 21.09 | 21.17 | 21.25 | 21.31 | 21.37 | 21.43 | 21.48 |
| 24.00 | 22.37 | 22.50 | 22.61 | 22.73 | 22.83 | 22.92 | 23.01 | 23.11 | 23.18 | 23.26 | 23.32 | 23.38 |
| 27.00 | 24.96 | 25.12 | 25.25 | 25.40 | 25.53 | 25.64 | 25.76 | 25.87 | 25.97 | 26.06 | 26.14 | 26.22 |
| 30.00 | 27.50 | 27.69 | 27.86 | 28.04 | 28.20 | 28.33 | 28.47 | 28.62 | 28.73 | 28.85 | 28.94 | 29.04 |
| 33.00 | 30.00 | 30.23 | 30.43 | 30.65 | 30.83 | 30.99 | 31.16 | 31.33 | 31.47 | 31.61 | 31.72 | 31.85 |
| 36.00 | 32.46 | 32.73 | 32.96 | 33.22 | 33.44 | 33.63 | 33.83 | 34.02 | 34.19 | 34.35 | 34.49 | 34.63 |
| 39.00 | 34.88 | 35.19 | 35.45 | 35.76 | 36.01 | 36.23 | 36.46 | 36.69 | 36.88 | 37.07 | 37.23 | 37.40 |
| 43.00 | 38.04 | 38.41 | 38.73 | 39.09 | 39.40 | 39.66 | 39.93 | 40.21 | 40.44 | 40.67 | 40.86 | 41.06 |
| 47.00 | 41.14 | 41.57 | 41.95 | 42.37 | 42.73 | 43.03 | 43.36 | 43.69 | 43.96 | 44.23 | 44.45 | 44.69 |
| 51.00 | 44.17 | 44.67 | 45.10 | 45.59 | 46.01 | 46.36 | 46.74 | 47.12 | 47.44 | 47.75 | 48.01 | 48.29 |
| 56.00 | 47.88 | 48.46 | 48.97 | 49.55 | 50.04 | 50.46 | 50.91 | 51.36 | 51.74 | 52.11 | 52.42 | 52.75 |
| 62.00 | 52.19 | 52.89 | 53.50 | 54.19 | 54.77 | 55.28 | 55.82 | 56.36 | 56.82 | 57.27 | 57.64 | 58.04 |
| 68.00 | 56.38 | 57.20 | 57.90 | 58.71 | 59.41 | 60.00 | 60.64 | 61.28 | 61.82 | 62.35 | 62.79 | 63.27 |
| 75.00 | 61.11 | 62.07 | 62.90 | 63.86 | 64.68 | 65.38 | 66.14 | 66.91 | 67.55 | 68.18 | 68.72 | 69.29 |
| 82.00 | 65.68 | 66.79 | 67.75 | 68.87 | 69.82 | 70.64 | 71.53 | 72.42 | 73.18 | 73.92 | 74.55 | 75.22 |
| 91.00 | 71.33 | 72.64 | 73.78 | 75.11 | 76.24 | 77.22 | 78.28 | 79.35 | 80.26 | 81.15 | 81.91 | 82.73 |

**Tables 3 and 4: Range 100 to 910.**

From Table 2 82 and 51 = 31.44
From Table 3 39 and 160 = 31.36
From Table 4 33 and 680 = 31.47

The choice depends on what you have in stock!

Now take the case where a 15.6k resistor is required. First look for the right *number*, in this case 15.6 and don't worry about the magnitude:

From Table 3 18 and 120 = 15.65
From Table 4 16 and 620 = 15.60

Now 15.6k is 1000 x 15.6 ohms (the value shown in the tables) so multiply both row and column by a factor of 1000.

The required values are 18k and 120k or 16k and 620k.

When a shunt value of 620k is used the tables indicate that any shunt value between 470k and 1M ohm will give the required result to within 1 per cent.

## TABULAR STICK-UP

You may find it convenient to stick the four tables together in line. There is a well known law in electronics which states that "Where information is contained on two or more sheets the user will invariably need to refer to both". The corollary of this is "Where cross references are made between two similar documents or charts one or both results will be misread".

PE

## LAWFUL REMINDER

**TOTAL OF RESISTORS IN SERIES**

RT = R1 + R2 + R3 .... etc.

**TOTAL OF RESISTORS IN PARALLEL**

$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$ .... etc.

**STANDARD DECADE VALUES**

E24 SERIES = 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91

E12 SERIES = 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82

E6 SERIES = 10, 15, 22, 33, 47, 68

**OHMS LAW**

EXPRESSIONS: $V=IR$, $R=\frac{V}{I}$, $I=\frac{V}{R}$

# SPACE WATCH

### BY DR PATRICK MOORE CBE

**Now is the time to plan your astro-hols. Book now for Bognor, Finland or Venus.**

I must, alas, begin with a warning. For some time past an organisation calling itself 'the International Star Registry' has been selling star names. Send them $35 or so, and you will receive a certificate and a map showing you the star which has been named according to your choice.

It goes without saying that this has no status whatsoever. It is equivalent to asking someone to pay $35 so that the name of, say, the Royal Festival Hall will be changed to 'John Smith Hall'. But this scheme is not harmless fun; it has been preying upon bereaved parents and others. One letter came to the office of *Astronomy Now* from a mother who had had a star 'named' after her dead three-year-old daughter.

Unfortunately, it seems that the scheme is not actually illegal. The organisers have kept within the law, and have made very large sums of money. I therefore urge you to publicise the real facts, and to urge people to have nothing whatever to do with it.

On a much more pleasant note, I am delighted to record that Arthur C. Clarke, the celebrated science-fiction writer (and author of the script of the film 2001) has been awarded the C.B.E. The ceremony took place in London; Arthur had flown in specially from his home in Sri Lanka. All readers of *Practical Electronics* will, I know, join me in congratulating him. *(PE staff do so as well. Ed)*

## A LOOK AHEAD

1989 is nearly over. It has been a mixed year in every way, including the astronomical aspect. Voyager 2 was a tremendous triumph, and the results from the Neptune pass exceeded all hopes. Against this, there was the virtual failure of the Hipparcos astrometric satellite, which was put into the wrong orbit when its on-board rocket 'booster' failed - either by design error, human error or both. It is still hoped to salvage something from the mission, and this will become apparent in 1990, but undoubtedly it has been a severe setback.

During 1990 we will have the planets on view at various times; Saturn comes to opposition in July, though it is still inconveniently far south, while Mars does so in late November, when it will be nearly as well placed as it was in 1988. For once there is no opposition of Jupiter - the next will be on 29 January 1991. No bright comets are expected, but, of course, one never knows.

Of the four 1990 eclipses, only two are visible from Europe. On February 9 there will be a total lunar eclipse which should be well seen from Britain - weather permitting; and on July 22 the track of the total eclipse of the Sun will cross the northern part of the continent, including Finland and parts of Russia. Various expeditions are being planned. If you consider visiting the Finnish lakes, book your tickets now - though it is true that the altitude of the Sun will be painfully low.

Of the various space-probes, Magellan is en route for Venus, and will reach the neighbourhood of its target in August; thereafter it will spend one Venus year at least (225 Earth days) in mapping the surface by radar. The Galileo probe is on its way to Jupiter, but because it has to take a roundabout route it will not arrive till 1995, by which time it will have by-passed Venus once and the Earth twice, as well as photographing two asteroids, Gaspra and Ida. The route reminds me rather of going from Bognor to Brighton by way of Grimsby, but with the resources available there was no alternative.

## THE DECEMBER SKY

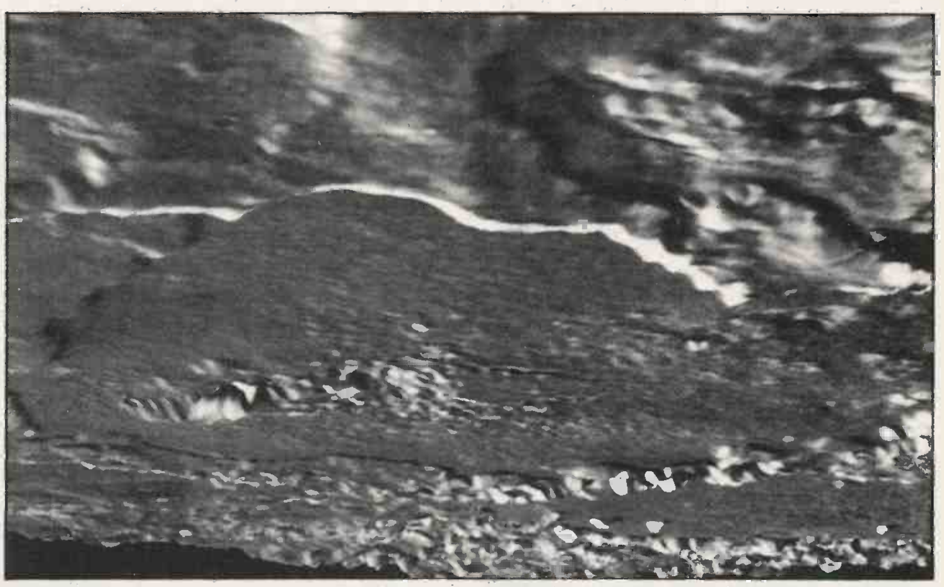
*Planetary enthusiasts have mixed fortunes this month. Mercury is theoretically in the evening sky, but it is a long way south of the celestial equator, and the only real chance of seeing it with the naked eye will be between Christmas and December 29. Venus, on the other hand, dominates the scene. It reaches its greatest brilliancy on December 14, and is then much brighter than any other object in the sky apart from the Sun and the Moon; it is in its crescent stage, as any telescope or even powerful binoculars will show. Venus far outshines Jupiter, even though the Giant Planet comes to opposition on December 27 and is then visible throughout the hours of darkness; it is in Gemini, and therefore ideally placed for observation. Of the other planets, Saturn has vanished into the evening twilight, while Mars is to be seen only shortly before dawn. Mars is in Scorpius, and on December 30 it is only 5 degrees away from Antares, so that it will be interesting to compare the two. The name 'Antares' means 'the Rival of Mars' (Ares) and the fiery colours are much the same, but at the moment Antares is about half a magnitude brighter than Mars.*

*The Moon is full on December 12, and new on the 28th. There are no solar or lunar eclipses this month. However, there are two major meteor showers, the Geminids (maximum on December 13) and the Ursids (December 22). Generally speaking the Geminids are the more spectacular of these showers, but this year the strong moonlight will interfere.*

*Winter skies are now with us - and this means Orion, the celestial Hunter, with his two leaders, the orange-red Betelgeux and the brilliant white Rigel. Upward, the three stars of the Belt show the way to Aldebaran, with the loose cluster of the Hyades, and then to the 'Seven Sisters' or Pleiades; how many of the Sisters can you count with the unaided eye? The record is said to be nineteen, but if you can reach a dozen you are doing very well indeed. The stars in the Pleiades make up a genuine cluster; they were formed at the same time from the same nebula, and by cosmical standards they are young, so that their leaders are hot, blue and energetic.*

*Capella, in Auriga (the Charioteer) is almost overhead, with the Great Bear 'standing on its tail' in the north-east. The Square of Pegasus is dropping in the west, and much of the low southern sky is occupied by the large but faint constellations of Eridanus (the River) and Cetus (the Whale).*

## THE ASHEN LIGHT



**This stunning landscape is on Triton, the largest satellite of Neptune, and was photographed during the Voyager 2 flyby. Photo by courtesy of NASA-JPL.**

When Venus is in the crescent stage, as it is during December, efforts will be made by serious observers of the planet to look for the Ashen Light, or faint visibility of the non-sunlit side of the planet. Conditions will be ideal, as the phase shrinks from 30 per cent at the start of December to only 12 per cent at the end.

When the Moon shows as a crescent, the 'unlit' part can often be seen shining faintly. There is no mystery about this; it is due to light reflected from the Earth on the Moon. (Leonardo da Vinci knew all about it!) But the same sort of effect, seen with Venus, is much less easy to account for. Venus has no moon, and light from the Earth would be much too feeble over a distance of over 24 million miles.

The so-called Ashen Light of Venus has been seen by almost all serious telescopic observers of the planet, though it is very elusive and, of course, very much dimmer than the Earthshine on the Moon. But it seems to be real, and it has to be explained. Earlier attempts were somewhat wild. Franz von Paula Guithuisen, a German astronomer of the mid-19th century, put it down to vast forest fires lit by the Venusians to celebrate the election of a new Government; other ideas involved shining oceans or regions of glowing vegetation. But the only really serious explanation which seems to be acceptable is that the Light is caused by electrical disturbances in Venus' upper atmosphere, so that in a way we are dealing with a more powerful version of our own aurorae.

The problem here is that according to all available measurements, Venus has no detectable magnetic field, and this would seem to cast doubt upon brilliant aurorae there. However, some sort of high-level atmospheric phenomenon must certainly be involved. True, a few astronomers dismiss the Light as pure illusion, but it has been seen too often and too clearly, and its reality is also confirmed by spectroscopic observation.

A good, steady telescope is needed for observations of the Ashen Light, and probably the minimum aperture is six inches for a Newtonian reflector or four inches for a refractor. Observations have to be made against a reasonably dark background, which means that Venus will be low down, but the effort is worth making - particularly now that the Sun is active, because if any auroral phenomena are involved they will be enhanced by what is happening on the Sun. So students of Venus look forward to an interesting time this December. PE

# INCREASING UCT PERFORMANCE

By Anthony H. Smith Bsc

**"Have you got the time?" "If you've got the interpolation"**

Even in its simplest form, the Universal Counter Timer is undeniably a versatile measurement system, and used within its limits even the cheapest model will prove an invaluable addition to anyone's collection of test gear. In fact, for an outlay of around $200 or so, we can afford to choose any one of several modestly-priced instruments on the market, most of which provide the basic measurement modes at acceptable levels of accuracy.

Demanding applications, however, require the use of a more sophisticated instrument whose performance has been improved in one or more of the following ways:

increased range of measurement (eg: frequency measurements greater than 10MHz, time measurements less than 100ns);

greater variety of measurement modes;

increased accuracy and resolution;

additional functions which enhance operating versatility and permit complex measurements on 'difficult' signals.

A variety of techniques is used to implement these improvements: some methods are relatively simple, requiring little modification to the basic uct architecture; the more complex techniques, however, usually entail considerable extra circuitry which inevitably pushes up the price (high performance ucts usually start at around $800, with top-flight models costing $2000, or more).

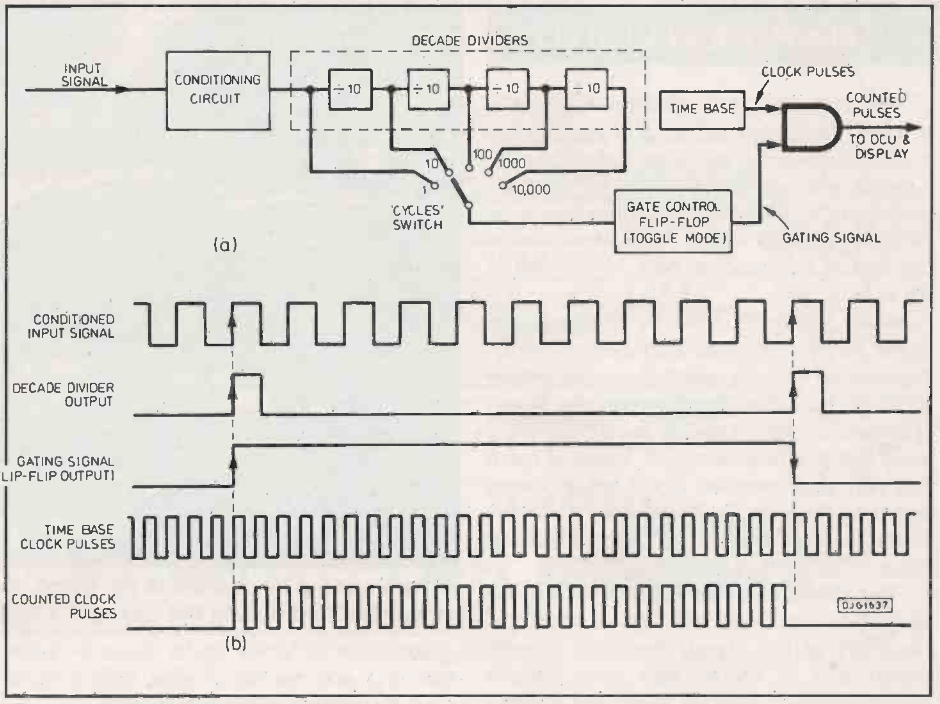


**Fig 1A. Multiple period averaging circuit**
**Fig 1B. Timing diagram for a ten period average.**

## IMPROVING TIME MEASUREMENTS

Two common techniques employed to enhance time measurements are Multiple Period Averaging and Time Interval Averaging, both of which are statistical processes used to reduce the effects of random errors.

We can understand the essence of these techniques by considering an analogy. Imagine we buy a box of 100 ohm resistors. Due to imperfections in the manufacturing process, none of these resistors can be exactly 100 ohms; instead, the values will deviate slightly from the nomimal resistance. For example, if the tolerance is ±5 per cent, the resistance could be as low as 95 ohms, or as high as 105 ohms.

If we take a resistor from the box and measure it with an ohmmeter, we may find the value to be 102 ohms; the next one might be 98 ohms, the next 103 ohms, and so on.

Each individual resistance measured in this way will be found to deviate from the nominal value in a random fashion due to the manufacturing tolerances. However, if we measure a large number of the resistors, the average resistance will tend towards the nominal value. In fact, the greater the number of samples, the closer will be the average value to the nominal resistance.

If we apply the same kind of averaging process to the measurement of signal period, we can reduce the effects of random errors such that the reading approaches the true value of the period. An additional benefit is that the resolution is improved, too.

The basic concept of multiple period averaging was introduced in Part One of this series (page 24, June 88). However, it is worth considering it in more detail, since both period averaging and time interval averaging are no longer restricted only to top-price ucts, but are now available on many of the cheaper models.

Fig. 1a shows the basic configuration for period averaging. The 'cycles' switch is used to select the number of input cycles (ie, periods) to be averaged. (This switch should not be confused with the 'range' switch of Fig. 4a, Part One, which determines the resolution and maximum value of the period measurement. Although the cycles switch also has an effect on the resolution and maximum value, its role as part of the averaging process is quite different to that of the range switch. However, many counters with the averaging facility only feature the cycles switch, which since it determines the 'range' of the averaging process - is often referred to as the range switch! To add to the confusion, the same switch usually doubles as the Gate Time selector when in frequency mode. Consequently, deciding which 'range' to choose can at first be a little bewildering: the only solution - if all else fails - is to refer to the instructions!)

In Fig. 1a, the input frequency is divided by a factor of ten before feeding the gate control flip-flop; consequently, the main gate is held open for the duration of ten input periods, thus accumulating ten times as many clock pulses as in a single period measurement. The timing diagram of Fig. 1b makes this clear.

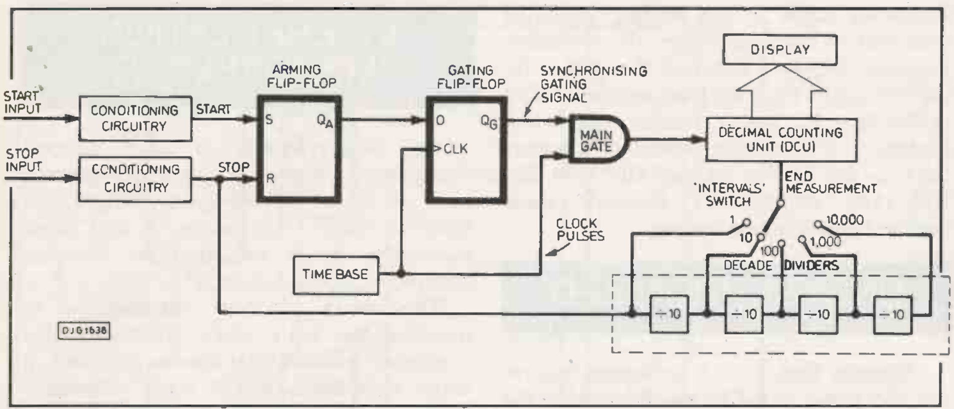


Fig 2. Arrangement for time interval averaging.

Let's assume the input period is, say, 12.3456us. With a time base clock period of 100ns, a single period measurement will accumulate 123 ± 1 clock pulses, producing a typical reading of 12.3us. However, by averaging the measurement over ten cycles, the counter will clock up 1234 ±1 clock pulses, which will be displayed as 12.34us.

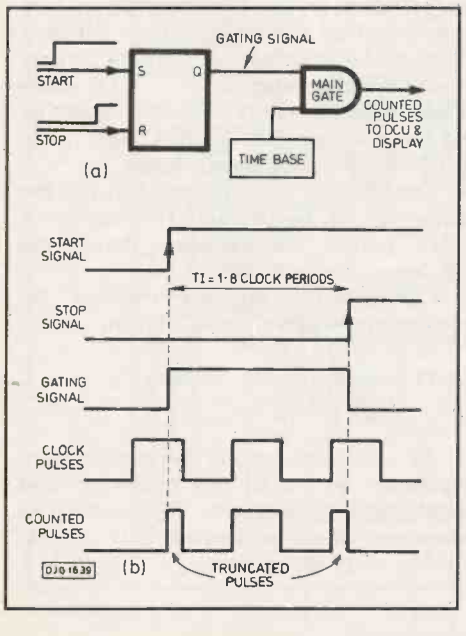
We can see that the resolution of the averaged measurement is ten times greater than that of a single period. Also, the relative magnitude of the ± count error is reduced by a factor of ten; in fact, period error is given by:

$$\text{Period Error} = \pm\frac{1\ \text{Count Error}}{N} \pm \frac{\text{Trigger Error}}{N} \pm \text{Time Base Error}$$

where N is the number of cycles averaged.

Trigger error, like the ±1 count error, is also reduced by the factor N, since it, too, is a random error. Time base error, on the other hand, is not a random error, and cannot be reduced by any amount of averaging. At first, this may seem a little surprising. However, consider again the box of resistors analogy: even though averaging the resistances gets us closer to the nominal value, the average itself is only as accurate as the ohmmeter used to make the measurements. So although period averaging can reduce random errors, it can never be used to improve the accuracy of the time base frequency standard.

Fig 3 (A). Direct gating
(B). Pulse truncation.



Furthermore, even though a large value of N means better measurement results, there is a limit to the number of periods which can be averaged. The number of digits in the uct's display poses the first restriction: every decade increase in N requires an extra digit in the reading to accommodate the increased resolution. Thus, too large a value of N will cause the display to overflow.

A second restriction concerns the measurement time, which is equal to: period x N. For example, averaging a 50Hz signal over 100,000 cycles will take over half an hour! As well as being rather tedious, the long measurement time is likely to minimise measurement accuracy due to drifts in the time base oscillator frequency.

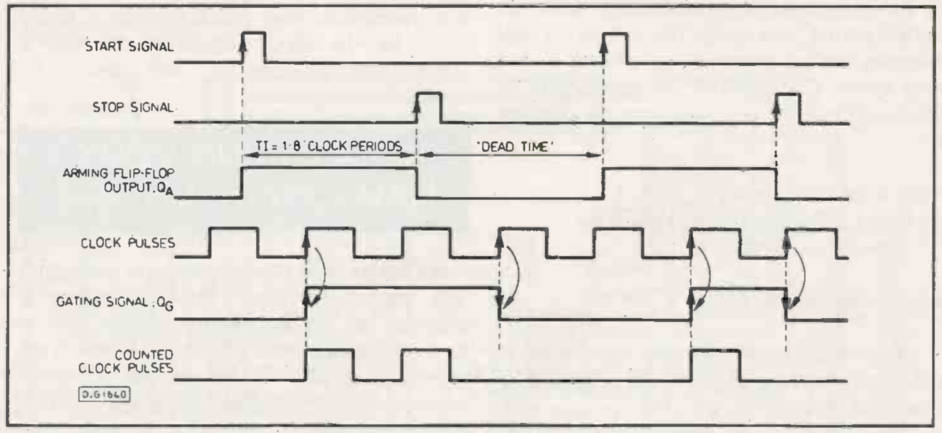


Fig 4. Synchronised gating for time interval averaging.

## TIME INTERVAL AVERAGING

Although time interval averaging is very similar to period averaging, there are one or two subtle differences which cause important variations in the technique.

Fig. 2 shows the time interval averaging circuit typical of most ucts (compare this with the circuit for single time interval measurements introduced in Fig. 5, page 23, Part One).

Unlike the period averaging circuit, the decade dividers are not used to extend the gate time, but instead determine the end of the measurement when the requisite number of time intervals has been averaged (the actual number, N, is advanced in decade steps by the 'intervals' switch). In fact, using the dividers to extend the gate time would produce a totally incorrect measurement, since the gate would be held open not only for the prescribed number of time intervals, but also for the same number of 'dead time' periods occurring between the time intervals, thus causing the decade counting unit to accumulate far too many clock pulses.

Consequently, the main gate must be opened only during each time interval; however, unlike the single interval measurement which ends after just one interval, the circuit of Fig. 2 allows the dcu to accumulate clock pulses during every successive interval. The measurement does not end until N 'stop' transitions (corresponding to N intervals) have been counted by the decade dividers.

## SYNCHRONISED GATING

Synchronised gating is essential for correct time interval averaging measurements. Last month, we saw how a direct gating circuit (as in Fig. 3) can produce a ±1 count error due to a lack of coherence between the input signal and the clock pulses. However, for some input signals, the error can actually be greater than one count.

An example is shown in Fig. 3b, where the time interval is equal to 1.8 clock periods. Because of the particular phase relationship between the time interval and the clock signal, a clock pulse is truncated at the beginning and end of the interval. If the dcu is fast enough, the truncated pulses will both be counted, producing a reading of three counts.

Consequently, the reading is in error by 3 - 1.8 = 1.2 counts, ie, by more than one count. For period averaging, this phenomenon is not a problem since it would occur only once during the entire measurement.

For time interval averaging, however, where the gate is opened and closed for every interval (no matter how many are averaged), the error will obviously accumulate, causing a significant bias in the counter reading which will invalidate the averaged measurement.

Fortunately, the problem can be solved by synchronising the gating signal with the clock signal. In Fig. 2, this is achieved using an 'arming' flip-flop in conjunction with the gating flip-flop: the operation is illustrated in Fig. 4. Because the gating flip-flop is clocked by the time base, its output at QG can only be integer multiples of the clock period, ie there is no longer any chance of truncation.

Note that synchronised gating cannot eliminate the ±1 count error, but does ensure than quantisation error is never more than one count: it remains for the averaging process itself to reduce the ±1 count error.

We can see how averaging works by considering the example in Fig. 4. For a 10MHz time base, the clock period is 100ns and the time interval is 1.8 x 100ns = 180ns. The figure shows how each time interval causes either one or two pulses to be accumulated. Consequently, for a single time interval measurement, (ie, N=1), the reading will be either 0.1us (=100ns), or 0.2us (=200ns), a far cry from the true value of 180ns.

However, the likelihood of counting two pulses is much greater than it is for just one, and in fact there is an 80 per cent chance of counting two pulses, and a 20 per cent chance of counting one. Thus, if we average the measurement over, say, N=100 intervals, 80 of them will cause two pulses to be counted, and 20 will cause one to be counted. So, at the end of the measurement, we will have accumulated (80 x 2) + (20 x 1) = 180 pulses, which is displayed as 180ns.

Obviously, the resolution is better than that of the single interval measurement. However, unlike period averaging, the resolution and accuracy are not improved by a factor N, but only by √N. Consequently, the accuracy of an averaged time interval measurement is given by:

$$\text{Time Interval Accuracy} = \pm\frac{1\ \text{Count}}{\sqrt{N}} \pm \frac{\text{Trigger Error}}{\sqrt{N}} \pm \text{Time Base}$$

Error +- Systematic Error

(Systematic error, like time base error, is not a random error, and so is not improved by averaging).

The presence of the square root is deduced statistically, and accounts for the fact that the random errors can occur in all the averaged intervals, unlike period averaging where random errors occur only once per measurement.

This can give rise to some confusion. For example, when we averaged the 180ns interval over 100 intervals, the number of significant digits in the reading increased from one to three. However, the resolution increases only by a factor of N = 100 = 10. (sq root signs) Thus, the least significant digit is, in fact, a random number, and some modern microprocessor-controlled counters (such as the Hewlett Packard HP5370A and HP5315A) automatically eliminate these random digits from the reading.

## UNSYNCHRONISED

Although time interval averaging requires that the gating signal be synchronised to the clock, it is essential that the timer interval repetition rate is NOT synchronous with the clock! This condition ensures that true statistical operation is achieved; in fact, if the interval frequency becomes coherent with the clock (ie, if the interval frequency becomes an exact submultiple of the time base frequency), the circuit behaves simply as a sampling system, and does not implement a true averaging process.

For example, if, in Fig. 4, the interval repetition rate was exactly, say, a third of the clock frequency, either just one, or just two pulses would always be counted during each interval, such that the reading would always appear to be 100ns or 200ns. This problem would exist no matter how many intervals were averaged.

To overcome this coherence problem, some high performance counters, such as the Hewlett Packard HP5345A, use a noise modulated time base which introduces phase jitter to the clock signal such that a synchronous relationship can never be established.

## MEASURING VERY NARROW INTERVALS

In addition to improvements in resolution and accuracy, time interval averaging provides an extra benefit, namely that it facilitates measurement of intervals which are shorter than the clock period! (This is impossible with a standard single interval measurement.)

Assume, for example, that we have a 100ns clock period, and a 20ns time interval. If we average the reading over, say, 100 intervals, there is a 20 per cent chance of counting one clock pulse, and an 80 per cent chance of counting no pulses. Thus, we accumulate (20 x 1) + (80 x 0) = 20 pulses, which is displayed as 20ns.

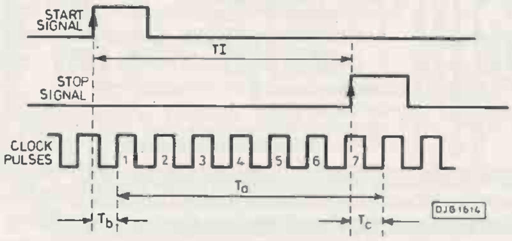


**Fig 5. Improved measurement by analogue interpolation.**

## INTERPOLATION IMPROVEMENT

One disadvantage of time interval averaging is that it requires a repetitive train of intervals; obviously, single-shot intervals cannot be averaged, and other techniques must be used to increase accuracy and resolution.

The most obvious solution is to increase the uct's clock frequency: for example, a 100MHz clock provides a single-shot resolution of 10ns, whereas a 500MHz clock brings this down to 2ns. However, even these values are poor compared to the picosecond resolution available with time interval averaging on models such as the HP5345A, or the Philips PM6652.

Nevertheless, 500MHz is, at present, about the highest practical clock frequency available, so for single-shot resolution better than 2ns, either anologue or digital interpolation must be used.

## ANALOGUE INTERPOLATION

Consider the waveforms shown in Fig. 5, where TI is a single-shot time interval. To measure TI, the uct actually measures three intervals, namely Ta, Tb, and Tc.

The unknown time interval is given by: TI = Ta + Tb - Tc.

Ta is measured simply by counting the number of clock pulses, Na, occuring between the start and stop signals. In Fig. 5, Na = 7, so assuming a 100ns clock period, Ta is simply 7 x 100 = 700ns.

The intervals Tb and Tc are measured using analogue interpolation. Consider Tb: as soon as the start pulse arrives, a constant current begins to charge a capacitor. When the charging is stopped (on the rising edge of clock pulse number 1), the voltage on the capacitor is proportional to Tb. The capacitor is then discharged by a constant current which is 1000 times less than the charging current. Thus, the discharge time is 1000 times longer than Tb, and is measured simply by counting the number of clock pulses, Nb, which occur during the discharge.

The interval Tc is measured in just the same way, ie, by counting the number of clock pulses, Nc, occuring during the discharge of a capacitor.

Consequently, the uct displays the precise time interval obtained from:

$$TI = \frac{Na}{1000} + \frac{Nb - Nc}{1000} \times 100ns.$$

As well as increasing the measurement resolution by 1000, this technique also results in a considerable improvement in accuracy which is limited only by the quality of the interpolators.

## DIGITAL INTERPOLATION

Various digital interpolation schemes have been developed; a particularly interesting version is known as the 'dual Vernier' technique, which, in addition to the time base oscillator, employs two phase-locked oscillators (plos). The plos are 'startable' oscillators, which means that their oscillation can be started by applying a trigger pulse. Once started, the oscillations remain phase-locked to the trigger pulse, and the frequency of oscillation is held constant.

In Fig. 6, the start signal triggers the first phase-locked oscillator, PLO1, and the stop signal triggers the second, PLO2.

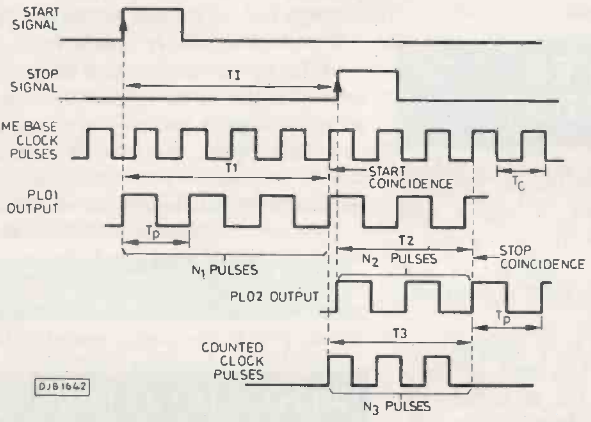


**Fig 6. Dual Vernier interpolation**

Both PLO1 and PLO2 are designed to have exactly the same frequency, ie, the period is the same for each one. This period, Tp, is arranged to be slightly longer than the clock period, Tc, and the two are related by: Tp = Tc(1+1/x), where x is the 'interpolation factor'.

After a time T1, the PLO1 output signal becomes phase coincident with the clock signal - this occurs at the 'start coincidence'. Similarly, after a time T2, the POL2 output also becomes coincident with the clock at the 'stop coincidence'. The number of PLO1 pulses, N1, occuring during T1 is recorded; similarly for N2. Also, the start and stop coincidences are used to gate a number of clock pulses, N3, during the time T3.

From the figure, we see that:

TI + T2 = T1 + T3 ; rearranging: TI = T1 + T3 - T2 .

But, T1 = N1.Tp = N1.Tc(1+1/x),

and T2 = N2.Tp = N2. Tc(1+1/x) .

Also, T3 = N3.Tc,

and so: TI = N1.Tc(1+1/x) + N3.Tc - N2.Tc(1;1/x) ;

simplifying: TI = Tc[N3 + (1+1/x).(N1 - N2)]

It is now a simple procedure for an arithmetic circuit to compute the time interval, TI, according to the above formula.

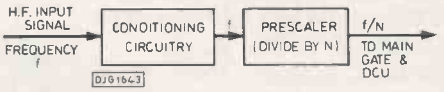
The actual resolution of the measurement depends on the choice of Tc and x, and is given by Tc/x. For example, in the Hewlett Packard HP5370A, Tc = 5ns and x = 256, giving an amazing single-shot resolution of 5ns/256 ≈ 20 picoseconds! (Incidentally, this order of resolution makes it possible for time-of-flight radar systems to measure target distances with a resolution of less than half a centimetre!)

Interestingly, the dual Vernier technique operates even if the stop signal arrives before the start signal: when this happens, the time interval is usually given a negative sign.

## MEASURING HIGH FREQUENCIES

In the basic frequency counting configuration introduced in Part One (page 22), the conditioned input signal is fed directly to the main gate and is counted by the dcu. Consequently, the maximum input frequency is limited by the speed of the logic devices which form these sections.

**Fig 7. Down conversion by prescaling**



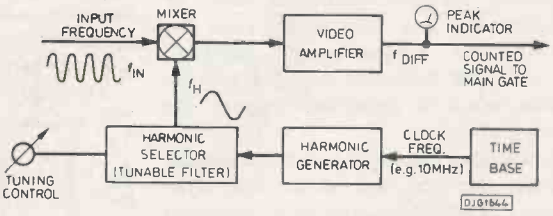


**Fig 8. Heterodyne down-converter**

On lower-priced ucts, the maximum frequency for direct gated measurements is usually around 10MHz, while the more expensive models can work at 100MHz, and beyond. For example, the HP5345A features direct gating up to 500MHz, while the Philips model PM6675 counts directly to 600MHz. To measure higher frequencies, special techniques must be used to 'down-convert' the input frequency to a value within the capabilities of the main gate and dcu.

## PRESCALING

Prescaling is the commonest and most straightforward down-conversion technique, and simply involves dividing the input frequency before it reaches the main gate - Fig. 7.

The prescaler ic is a high speed device which reduces the frequency by the division factor N. If, for example, the main gate can work only up to 10MHz, and we wish to measure signals as high as 1GHz (109Hz), we require a prescaler with N=100, and which can toggle at the desired 1GHz frequency. (This could be achieved, for example, by cascading two Plessey devices, namely the SP8665B followed by the SP8660B.)

Prescaling has the disadvantage that the measurement resolution is reduced by the factor N. For example, the direct gating PM6675 can display a frequency of, say, 543.219876MHz with all nine significant figures for a one second gate time. On a counter prescaled by N=100, however, the frequency at the main gate would be 5.43219876MHz, such that 5432198 counts would be accumulated during a one second gate time, producing a reading of 543.2198MHz only seven significant figures. The only way to maintain resolution is to increase the gate time by the factor N, which in this case would mean a measurement time of 100 seconds.

Counters such as the Hewlett Packard HP5386A can prescale input frequencies as high as 3GHz: the measurement of higher frequencies, however, requires different techniques.

## HETERODYNE CONVERTER

A typical example of a manually-tuned heterodyne down-converter is shown in Fig. 8.

The 10MHz clock signal from the time base is fed to the harmonic generator (for example, a step recovery diode) whose output is a range of discrete frequencies spaced at 10MHz intervals, ie, 10MHz, 20MHz, 30MHz, etc.

The variable tuning of the harmonic selector is used to pick out just one of these harmonics, fH, which is mixed with the input frequency, fin, in the mixer. 'Mixing' in this sense means multiplying the two sinusoids together. If we represent the input signal as: input = Acos 2π fint, and the selected harmonic as: harmonic = Bcos 2π fHt, then using the trigonometric identity: cosX.cosY = 1/2cos(X-Y), we find that:

input x harmonic = 1/2ABcos 2 (fin+fH)t + 1/2ABcos 2 (fin-fH)t.

In other words, the mixer output signal has two sinusoidal components, one at a

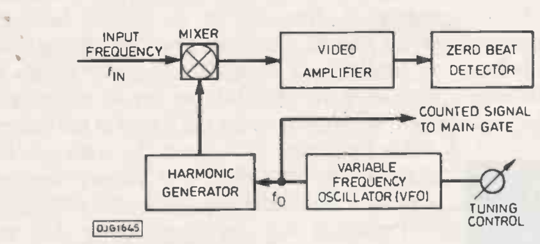


**Fig 9. Basic transfer oscillator.**

frequency (fin+fH), the other at a frequency (fin-fH). Now, the video amplifier is designed to have a bandwidth from, say, 100kHz to 10MHz, such that signals outside this range are attenuated. Consequently, the sum frequency, (fin+fH), being much higher than 10MHz, is attenuated, whereas the difference frequency, (fin-fH), lies within the amplifier bandwidth and is amplified accordingly.

The amplified difference frequency - call if fDIFF - is fed to the main gate of the counter and measured in the normal fashion. Consequently, the counter reads fDIFF, but because fDIFF = fin - fH, we can determine fin simply by adding the harmonic frequency (which is read from the tuning dial) to fDIFF.

An example should make this clear. Assume the unknown input frequency is fin = 437MHz. Starting at the low end of the tuning dial, we tune up to the first harmonic that gives a maximum reading on the peak indicator (this tells us that a difference frequency within the amplifier bandwidth has been obtained). In this case, the harmonic will be fH = 430MHz. Next, we read off the value of fDIFF from the display, (which will be fDIFF = 437MHz - 430MHz = 7MHz), and calculate fin from fin = fH + fDIFF = 430MHz + 7MHz = 437MHz.

The heterodyne technique allows us to measure frequencies as high as 20 - 30GHz (well into the microwave range), and measurement accuracy is limited only by quantisation and time base errors, since the down-conversion introduces no additional errors. Also, the technique does not degrade resolution, which is determined only by the counter's gate time.

The difference frequency must be continuous for correct operation, and so the heterodyne technique can only work with cw (continuous-wave) signals (ie, pulsed radio frequency cannot normally be accommodated). However, the system is highly tolerant of modulated inputs, and can measure signals with as much as 50 per cent amplitude modulation, and 40MHz peak-peak frequency modulation.

Although this method has benefitted considerably from recent developments, it is not a new technique; in fact, it has been used (in a slightly different form) for many years in superheterodyne radio receivers.

## TRANSFER OSCILLATOR

Several variations of the transfer oscillator down-converted have been developed, and practically all of them depend upon relating a measurable, low-frequency signal to the unknown input frequency in order to determine the latter.

The technique is shown in its simplest form in Fig. 9. The variable frequency oscillator output (frequency f0), is fed to a harmonic generator which produces a range of harmonics of f0 up to the 100th harmonic. These harmonics are then combined with fin in the mixer in order to produce a range of sum and difference frequencies. Those difference frequencies within the bandwidth of the video amplifier are amplified and used to drive a 'zero beat detector'. This detector indicates a zero-signal condition, which occurs when the difference frequency (fin-Nf0) equals zero, N being the particular harmonic involved.

Obviously, when fin - Nf0 = 0, then fin = Nf0, and we can determine fin by counting f0 in the usual way and multiplying the reading by N. But there is a problem - we do not know which harmonic of f0 is zero beating with fin, ie, we don't know the value of N. Fortunately, we can circumvent this problem using the following simple procedure.

Starting at a low value of f0, we adjust the tuning until a zero beat occurs at fin = Nf01. Then, by increasing f0 from f01 to f02, we obtain a second zero beat occuring at fin = (N-1)f02, ie when fin zero beats with a harmonic of f02 one less than the Nth harmonic of f01. Consequently:

$$fin = Nf01 = (N-1)f02, \text{ and so :}$$

$$fin = \frac{f01.f02}{f02-f01} \; ,$$

and thus, by measuring f01 and f02, we can calculate fin without any knowledge of the harmonics involved.

For example, assume the vfo can be tuned over the range 100-200MHz, and that fin = 3.6GHz. A zero beat will occur at f01 = 144MHz, and that fin (ie, 3.6GHz - (25 x 144MHz) = 0). When f0 is increased slightly to f02 = 150MHz, the 24th harmonic of f02 is zero beating with fin (ie, 3.6GHz - (24 x 150MHz) =0).

$$\text{Thus: } fin = \frac{144MHz \times 150MHz}{150MHz - 144MHz} = 3.6GHz.$$

Although the measurement resolution can be as good as that of the heterodyne converter, the accuracy depends not only on quantisation and time base errors, but also on several other factors, such as the precision in detecting zero beat, and upon any drifts in the vfo frequency.

However, the transfer oscillator can measure almost any type of input signal (continuous-wave), amplitude modulated, frequency modulated, pulsed, or a combination of all four) over a wide frequency range extending to around 40GHz.

## AUTOMATIC DIVIDERS

Most modern microwave counters employ automatic versions of the above techniques, where the tuning, processing and arithmetic manipulation are all carried out electronically. Such schemes are usually called automatic dividers. There is also a system which combines the best features of the heterodyne and transfer oscillator techniques, and is known as the 'harmonic heterodyne converter'. This hybrid technique is employed in the Hewlett Packard HP5343A which can count frequencies up to 26.5GHz without requiring any manual adjustment.

**To be continued next month.**

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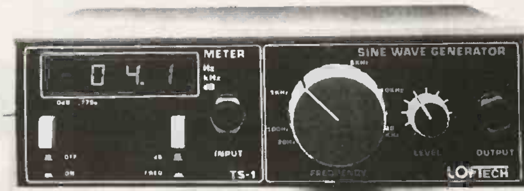

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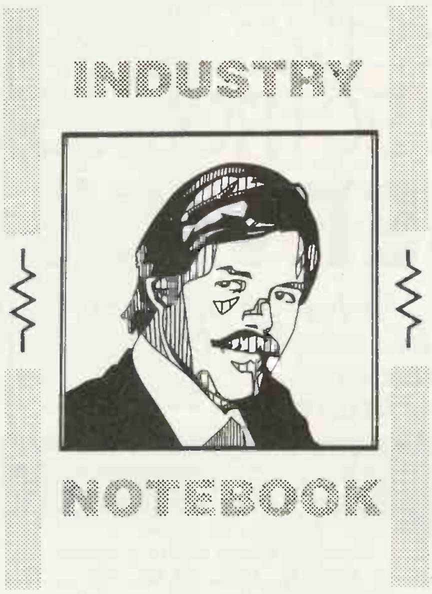
# CO-OPERATION IN COMPETITION

**By Tom Ivall**

## International co-operation is very desirable, but beware loss of identity.



The UK must now look to Europe for any further industrial success in integrated circuits. Which is an optimistic way of saying that there are no longer any British-owned manufacturers in this sector, at least in world market terms. During 1988 we saw the last two firms go. Inmos was sold to the French-Italian group SGS-Thomson Microelectronics. Then, as an outcome of the big takeover, Plessey Semiconductors passed into the hands of the German-British company GEC-Siemens.

As the Plessey chip business is held 50 per cent by GEC and 50 per cent by Siemens you could, of course, say that half of Plessey is still British-owned. But the Plessey activities are to be managed by Siemens, which is the dominant partner in this field (its semiconductor division having an annual turnover of about $520 million). So it seems pretty certain that the business will be amalgated or rationalised more with Siemens' interests than with GEC's.

Certainly the UK still has a small industrial presence in microchips through the integrated circuits made by GEC subsidiary Marconi Electronics Devices Ltd at Lincoln. But how this will fare as an independent producer in the face of the huge R&D expenditure needed just to stay afloat in the chip industry is by no means clear.

## INTEGRATION

Some readers may think *Industry Notebook* has become rather obsessive about integrated circuits in commenting so much about this sector. Many, however, will be well aware - for example from PE's regular *Chip Count* feature and the content of the technical articles - that ics have become absolutely central to electronics technology and manufacturing.

As the possible integration density keeps on rising, more and more of the circuitry of electronic equipment is moving onto semiconductor chips. Over the past five years, for example, the proportion of ics in the total world sales of electronic components has risen from 38 per cent to 50 per cent. And experts predict that from 1990 onwards some two-thirds of all components going into equipment will be ics.

Thus companies with a strong position in integrated circuits are getting a powerful grip on electronics manufacturing in general. And those who are able to divert enough of their profits into R&D to keep on bringing out new, more advanced chips are acquiring a strong influence over the design of electronic equipment. Once an equipment manufacturer is benefiting competitively through design features which regularly result from new ics coming from a particular chip maker he is not easily attracted away by the products of rival semiconductor firms.

But the almost complete absorption of UK chip manufacturing into the wider European industry has not done very much for the European firms in general. There are now three major producers here: Philips, SGS-Thomson and Siemens. All are greatly concerned about the increasing success of the Japanese semiconductor firms in Europe.

## COMPETING CO-OP

Part of the response has been "If you can't beat 'em, join 'em". This shows itself in various technology and commercial agreements between the European and Japanese companies. So here we have the phenomenon of trading adversaries from different cultures (occidental and oriental) co-operating with each other. At the same time we see trading adversaries from the same culture (European in one case, Japanese in the other) co-operating with each other to compete more effectively with the common industrial adversary from a different culture.

In Japan, for example, the competing chip firms have a common national aim: of expanding into Western European markets. In Europe the chip makers are banding together, against the Japanese commercial onslaught, through the Eureka scheme for promoting collaborative projects in advanced technology. As you may know, the members of Eureka are the governments of the twelve EC states, six EFTA countries and Turkey.

The Eureka project concerned with integrated circuits is a research programme for vlsi technology and applications originally called JESSI (Joint European Submicron Silicon). One aim is to produce sub-micron vlsi structures with an integration density of 100 million devices per chip by 1996. The plan was launched in 1988 by Belgium, France, Germany, Italy and the Netherlands (where was the UK?) and is reckoned to need an R&D investment of $2.5 billion spread over eight years.

Across the Atlantic something similar is happening. In spite of the early success of American vlsi firms in world markets, the semiconductor industry there is now, like the European one, extremely worried by the effectiveness of the Japanese dumping. More recently we have seen the unexpected sight - in a land where the ideology of free enterprise and unrestrained competition is probably at its purest and strongest - of some of the biggest firms in the electronics industry getting together to set up a common front against the foreign threat.

## MAGNIFICENT SEVEN

Seven companies have announced their intention to form a collaborative venture called US Memories Inc. Its main purpose is to try to reclaim some part of the dram memory market which US manufacturers have lost to the Japanese. The 'magnificent seven' are: Advanced Micro Devices, Digital Equipment, Hewlett-Packard, IBM, Intel, LSI Logic and National Semiconductor. About thirty other American firms have expressed interest.

At present the world dram market - worth about $3.5 billion per annum - is completely dominated by the Japanese, who have captured 87 per cent of it. The remaining 13 per cent is shared between the USA (7 per cent), Korea (4 per cent) and Europe (2 per cent). US Memories Inc hopes to increase the American share to about 12 per cent by 1992. Technologically its effort will be centred on the 4-Mbit memory.

These events are a topical input to the continuing debate about free-market versus state-controlled economies, degrees of government intervention and the possibilities of mixed systems. The inadequacies of the Soviet Union's and Polish economies show what can happen when industry is totally state controlled. Obviously free enterprise under capitalism is a highly effective stimulus to economic development. But untrammelled competition for markets across national frontiers leads to some countries losing their own industries. Perhaps we still need collectivism in some form or other. PE

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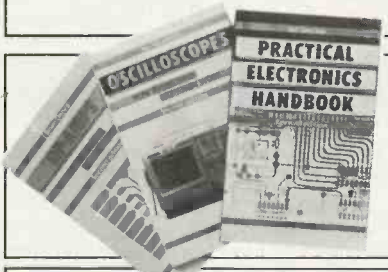

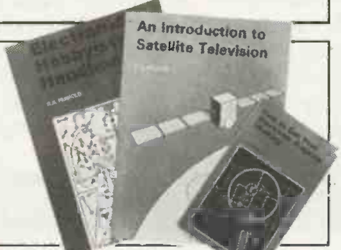

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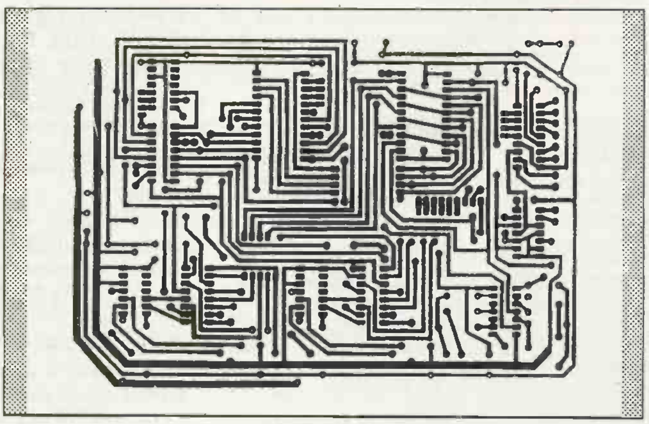

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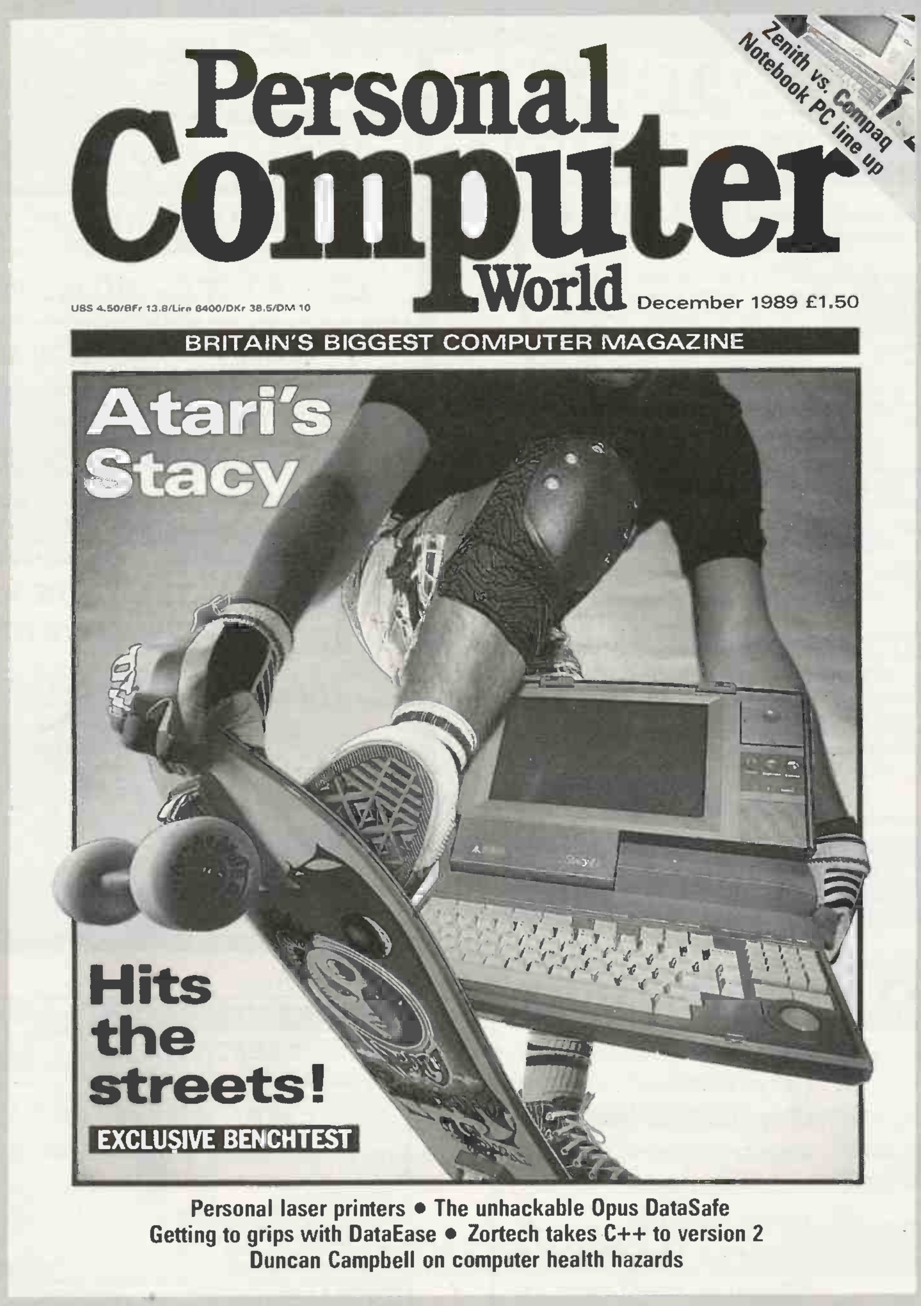

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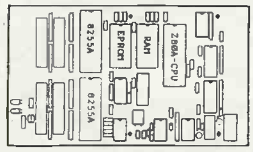

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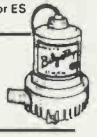

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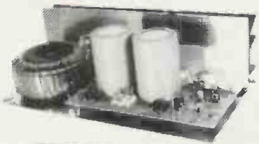
**OMP POWER AMPLIFIER MODULES** Now enjoy a world-wide reputation for quality, reliability and performance at a realistic price. Four models available to suit the needs of the professional and hobby market, i.e., Industry, Leisure, Instrumental and Hi-Fi etc. When comparing prices, NOTE all models include Toroidal power supply, Integral heat sink, Glass fibre P.C.B., and Drive circuits to power compatible Vu meter. Open and short circuit proof.

### THOUSANDS OF MODULES PURCHASED BY PROFESSIONAL USERS

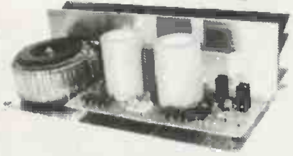
**OMP100 Mk 11 Bi-Polar** Output power 110 watts R.M.S. into 4 ohms, Frequency Response 15Hz – 30KHz –3dB, T.H.D. 0.01%, S.N.R. –118dB, Sens. for Max. output 500mV at 10K, Size 355 × 115×65mm.
**PRICE £33.99 + £3.00 P&P.**

### NEW SERIES II MOS-FET MODULES

**OMP/MF 100 Mos-Fet** Output power 110 watts R.M.S. into 4 ohms, Frequency Response 1Hz – 100KHz –3dB, Damping Factor, >300, Slew Rate 45V/uS, T.H.D. Typical 0.002%, Input Sensitivity 500mV, S.N.R. –125dB. Size 300 × 123 × 60mm.
**PRICE £39.99 + £3.00 P&P.**

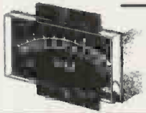


**OMP/MF200 Mos-Fet** Output power 200 watts R.M.S. into 4 ohms, Frequency Response 1Hz – 100KHz –3dB, Damping Factor >300, Slew Rate 50V/uS, T.H.D. Typical 0.001%, Input Sensitivity 500mV, S.N.R. –130dB. Size 300 × 155 × 100mm.
**PRICE £62.99 + £3.50 P&P.**



**OMP/MF300 Mos-Fet** Output power 300 watts R.M.S. into 4 ohms, Frequency Response 1Hz – 100KHz –3dB, Damping Factor >300, Slew Rate 60V/uS, T.H.D. Typical 0.0008%, Input Sensitivity 500mV, S.N.R. –130dB. Size 330 × 175 × 100mm.
**PRICE £79.99 + £4.50 P&P.**

NOTE:— MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS, STANDARD — INPUT SENS, 500mV BAND WIDTH 100KHz. PEC (PROFESSIONAL EQUIPMENT COMPATABLE) — INPUT SENS, 775mV, BAND WIDTH 50KHz, ORDER STANDARD OR PEC



**Vu METER** Compatible with our four amplifiers detailed above. A very accurate visual display employing 11 L.E.D. diodes (7 green, 4 red) plus an additional on/off indicator. Sophisticated logic control circuits for very fast rise and decay times. Tough moulded plastic case, with tinted acrylic front. Size 84 × 27 × 45mm.
**PRICE £8.50 + 50p P&P.**

## LOUDSPEAKERS

**LARGE SELECTION OF SPECIALIST LOUDSPEAKERS AVAILABLE, INCLUDING CABINET FITTINGS, SPEAKER GRILLES, CROSS-OVERS AND HIGH POWER, HIGH FREQUENCY BULLETS AND HORNS, LARGE S.A.E. (30p STAMPED) FOR COMPLETE LIST.**

## McKENZIE:— INSTRUMENTS, P.A., DISCO, ETC.

**ALL McKENZIE UNITS 8 OHMS IMPEDENCE**

**8″ 100 WATT C8100GPM** GEN. PURPOSE, LEAD GUITAR, EXCELLENT MID., DISCO.
RES, FREQ, 80Hz. FREQ, RESP, TO 14KHz. SENS, 99dB. .......... **PRICE £28.59 + £2.00 P&P.**
**10″ 100 WATT C10100GP** GUITAR, VOICE, ORGAN, KEYBOARD, DISCO, EXCELLENT MID.
RES, FREQ, 70Hz. FREQ. RESP, TO 6KHz. SENS, 100dB. .......... **PRICE £34.70 + £2.50 P&P.**
**10″ 200 WATT C10200GP** GUITAR, KEYBOARD, DISCO, EXCELLENT HIGH POWER MID.
RES, FREQ, 45Hz. FREQ, RESP, TO 7KHz. SENS, 103dB. .......... **PRICE £47.48 + £2.50 P&P.**
**12″ 100 WATT C12100GP** HIGH POWER GEN, PURPOSE, LEAD GUITAR, DISCO.
RES, FREQ, 45Hz. FREQ, RESP, TO 7KHz. SENS, 98dB. .......... **PRICE £36.66 + £3.50 P&P.**
**12″ 100 WATT C12100TC** TWIN CONE) HIGH POWER WIDE RESPONSE, P.A., VOICE, DISCO.
RES, FREQ, 45Hz. FREQ, RESP. TO 14KHz. SENS, 100dB. .......... **PRICE £37.63 + £3.50 P&P.**
**12″ 200 WATT C12200B** HIGH POWER BASS, KEYBOARDS, DISCO, P.A.
RES, FREQ, 40Hz. FREQ, RESP, TO 7KHz. SENS, 100dB. .......... **PRICE £64.17 + £3.50 P&P.**
**12″ 300 WATT C12300GP** HIGH POWER BASS LEAD GUITAR, KEYBOARDS, DISCO, ETC.
RES, FREQ, 45Hz. FREQ, RESP, TO 5KHz. SENS, 100dB. .......... **PRICE £85.79 + £3.50 P&P.**
**15″ 100 WATT C15100BS** BASS GUITAR, LOW FREQUENCY, P.A., DISCO.
RES, FREQ, 40Hz. FREQ. RESP, TO 5KHz. SENS, 98dB. .......... **PRICE £53.70 + £4.00 P&P.**
**15″ 200 WATT C15200BS** VERY HIGH POWER BASS.
RES, FREQ, 40Hz. FREQ, RESP. TO 4KHz. SENS, 99dB. .......... **PRICE £73.26 + £4.00 P&P.**
**15″ 250 WATT C15250BS** VERY HIGH POWER BASS.
RES, FREQ, 40Hz. FREQ. RESP, TO 4KHz. SENS, 99dB. .......... **PRICE £80.53 + £4.50 P&P.**
**15″ 400 WATT C15400BS** VERY HIGH POWER. LOW FREQUENCY BASS.
RES, FREQ, 40Hz. FREQ, RESP, TO 4KHz. SENS, 102dB. .......... **PRICE £94.12 + £4.50 P&P.**
**18″ 400 WATT C18404BS** EXTREMELY HIGH POWER, LOW FREQUENCY BASS.
RES, FREQ, 27Hz. FREQ, RESP, TO 3KHz. SENS, 99dB. .......... **PRICE £167.85 + £5.00 P&P.**

## EARBENDERS:— HI-FI, STUDIO, IN-CAR, ETC.

**ALL EARBENDER UNITS 8 OHMS EXCEPT EB8-50 AND EB10-50 DUAL 4 AND 8 OHM.**
**BASS, SINGLE CONE, HIGH COMPLIANCE, ROLLED FOAM SURROUND**

**8″ 50 WATT EB8-50** DUAL IMPEDENCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR.
RES, FREQ, 40Hz. FREQ, RESP, TO 7KHz. SENS, 97dB. .......... **PRICE £8.90 + £2.00 P&P.**
**10″ 50 WATT EB10-50** DUAL IMPEDENCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR.
RES, FREQ, 40HZ. FREQ, RESP, TO 5KHz. SENS, 99dB. .......... **PRICE £12.00 + £2.50 P&P.**
**10″ 100 WATT EB10-100** BASS, HI-FI, STUDIO.
RES, FREQ, 35Hz. FREQ, RESP, TO 3KHz. SENS, 96dB. .......... **PRICE £27.50 + £3.50 P&P.**
**12″ 60 WATT EB12-60** BASS, HI-FI, STUDIO.
RES, FREQ, 28Hz. FREQ, RESP, TO 3KHz. SENS, 92dB. .......... **PRICE £21.00 + £3.00 P&P.**
**12″ 100 WATT EB12-100** BASS, STUDIO, HI-FI, EXCELLENT DISCO.
RES, FREQ, 26Hz. FREQ, RESP. TO 3KHz. SENS, 93dB. .......... **PRICE £32.00 + £3.50 P&P.**

**FULL RANGE TWIN CONE, HIGH COMPLIANCE, ROLLED SURROUND**

**5¼″ 60 WATT EB5-60TC** (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES, FREQ, 63Hz. FREQ, RESP, TO 20KHz. SENS, 92dB. .......... **PRICE £9.99 + £1.50 P&P.**
**6½″ 60 WATT EB6-60TC** (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES, FREQ, 38Hz. FREQ, RESP, TO 20KHz. SENS, 94dB. .......... **PRICE £10.99 + £1.50 P&P.**
**8″ 60 WATT EB8-60TC** (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES, FREQ, 40Hz. FREQ, RESP, TO 18KHz. SENS, 89dB. .......... **PRICE £12.99 + £1.50 P&P.**
**10″ 60 WATT EB10-60TC** (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES, FREQ, 35Hz. FREQ. RESP, TO 12KHz. SENS, 86dB. .......... **PRICE £16.49 + £2.00 P&P.**

## TRANSMITTER HOBBY KITS

**PROVEN TRANSMITTER DESIGNS** INCLUDING GLASS FIBRE PRINTED CIRCUIT BOARD AND HIGH QUALITY COMPONENTS COMPLETE WITH CIRCUIT AND INSTRUCTIONS

**3W FM TRANSMITTER** 80-108MHz, VARICAP CONTROLLED PROFESSIONAL PERFORMANCE, RANGE UP TO 3 MILES, SIZE 38 × 123mm, SUPPLY 12V @ 0.5AMP, PRICE £14.49 + £1.00 P&P

**FM MICRO TRANSMITTER (BUG)** 100-108MHz VARICAP TUNED COMPLETE WITH VERY SENS FET MIC, RANGE 100-300m, SIZE 56 × 46mm. SUPPLY 9V BATT, PRICE £8.62 + £1.00 P&P

3 watt FM Transmitter

POSTAL CHARGES PER ORDER £1.00 *MINIMUM*. OFFICIAL ORDERS WELCOME FROM SCHOOLS, COLLEGES, GOVT. BODIES, ETC. PRICES INCLUSIVE OF V.A.T. SALES COUNTER. VISA ACCESS ACCEPTED BY POST, PHONE OR FAX.

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★ MANUAL ARM ★ STEEL CHASSIS ★ ELECTRONIC SPEED CONTROL 33 & 45 ★ VARI PITCH CONTROL ★ HIGH TORQUE SERVO DRIVEN DC MOTOR ★ TRANSIT SCREWS ★ 12″ DIE CAST PLATTER ★ NEON STROBE ★ CALIBRATED BAL WEIGHT ★ REMOVABLE HEAD SHELL ★ ½″ CARTRIDGE FIXINGS ★ CUE LEVER ★ POWER 220/240V 50/60Hz ★ 390×305mm ★ SUPPLIED WITH MOUNTING CUT-OUT TEMPLATE.

**PRICE £59.99 + £3.50 P&P.**

### OPTIONAL MAGNETIC CARTRIDGES

**STANTON AL500**
**PRICE £16.99 + 50p P&P**

**GOLDRING G850**
**PRICE £6.99 + 50p P&P**

## OMP MOS-FET POWER AMPLIFIERS, HIGH POWER, TWO CHANNEL 19 INCH RACK

**THOUSANDS PURCHASED BY PROFESSIONAL USERS**

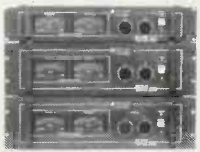
### NEW MXF SERIES OF POWER AMPLIFIERS

THREE MODELS:— **MXF200** (100w + 100w)
**MXF400** (200w + 200w) **MXF600** (300w + 300w)

All power ratings R.M.S. into 4 ohms.

**FEATURES:** ★ Independent power supplies with two Toroidal Transformers ★ Twin L.E.D. Vu meters ★ Rotary indended level controls ★ Illuminated on/off switch ★ XLR connectors ★ Standard 775mV inputs ★ Open and short circuit proof ★ Latest Mos-Fets for stress free power delivery into virtually any load ★ High slew rate ★ Very low distortion ★ Aluminium cases ★ MXF600 Fan Cooled with D.C. Loudspeaker and Thermal Protection.

**USED THE WORLD OVER IN CLUBS, PUBS, CINEMAS, DISCOS ETC.**

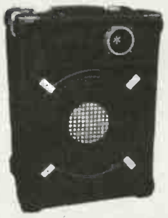


SIZES:— MXF 200 W19″×H3½″ (2U)×D11″
MXF 400 W19″×H5¼″ (3U)×D12″
MXF 600 W19″×H5¼″ (3U)×D13″

PRICES: **MXF200 £171.35**
**MXF400 £228.85**
**MXF600 £322.00**
SECURICOR DELIVERY £12.00 EACH

## OMP LINNET LOUDSPEAKERS

THE VERY BEST IN QUALITY AND VALUE



MADE ESPECIALLY TO SUIT TODAY'S NEED FOR COMPACTNESS WITH HIGH OUTPUT SOUND LEVELS. FINISHED IN HARDWEARING BLACK VYNIDE WITH PROTECTIVE CORNERS, GRILLE AND CARRYING HANDLE, INCORPORATES 12″ DRIVER PLUS HIGH FREQ. HORN FOR FULL FREQ. RANGE: 45Hz-20KHz BOTH MODELS 8 OHM, SIZE H18″ × W15″ × D12″.

CHOICE OF TWO MODELS

POWER RATINGS QUOTED IN WATTS RMS FOR EACH CABINET

**OMP 12-100 (100W 100dB) PRICE £159.99 PER PAIR**
**OMP 12-200 (200W 102dB) PRICE £209.99 PER PAIR**

SECURICOR DEL.:— £12.00 PER PAIR

## OMP SLIDE DIMMER 1K WATT & 2.5K WATT

CONTROLS LOADS UP TO 1KW & 2.5KW, SUITABLE FOR RESISTIVE AND INDUCTIVE LOADS BLACK ANODISED CASE, READILY FLUSH MOUNTED THROUGH PANEL/CABINET CUT-OUTS, **ADVANCED FEATURES INCLUDE:—**

- FULL 65mm SLIDE TRAVEL
- NEON MONITOR INDICATOR
- FLASH OVERRIDE BUTTON
- HIGH & LOW LEVEL PRESETS
- FULLY SUPPRESSED TO BS 800

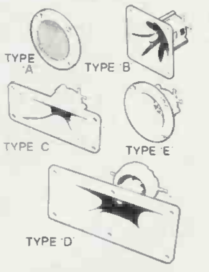
SIZES:—
1KW H128×W40×D55mm
2.5KW H128×W76×D79mm

**PRICES:— 1K WATT £15.99**
**2.5K WATT £24.99 + 60p P&P**

## PIEZO ELECTRIC TWEETERS-MOTOROLA

PIEZO ELECTRIC TWEETERS — MOTOROLA

Join the Piezo revolution. The low dynamic mass (no voice coil) of a Piezo tweeter produces an improved transient response with a lower distortion level than ordinary dynamic tweeters. As a crossover **is not** required these units can be added to existing speaker systems of up to 100 watts (more if 2 put in series). **FREE EXPLANATORY LEAFLETS SUPPLIED WITH EACH TWEETER.**



**TYPE 'A' (KSN2036A)** 3″ round with protective wire mesh, ideal for bookshelf and medium sized Hi-fi speakers. **Price £4.90 each** + 50p P&P.
**TYPE 'B' (KSN1005a)** 3½″ super horn. For general purpose speakers, disco and P.A. systems etc. **Price £5.00 each** + 50p P&P.
**TYPE 'C' (KSN6016A)** 2″×5″ wide dispersion horn. For quality Hi-fi systems and quality discos etc. **Price £6.99** each + 50p P&P.
**TYPE 'D' (KSN1025A)** 2″×6″ wide dispersion horn. Upper frequency response retained extending down to mid range (2KHz). Suitable for high quality Hi-fi systems and quality discos. **Price £9.99 each** + 50p P&P.
**TYPE 'E' (KSN1038A)** 3¾″ horn tweeter with attractive silver finish trim. Suitable for Hi-fi monitor systems etc. **Price £5.99 each** + 50p P&P.
**LEVEL CONTROL** Combines on a recessed mounting plate, level control and cabinet input jack socket. 85×85mm. **Price £3.99** + 50p P&P.

## STEREO DISCO MIXER

**STEREO DISCO MIXER** with 2 × 5 band L & R graphic equalisers and twin 10 segment L.E.D. Vu Meters. **Many outstanding features** 5 Inputs with individual faders providing a useful combination of the following:— 3 Turntables (Mag). 3 Mics. 4 Line including CD plus Mic with talk over switch Headphone Monitor. Pan Pot L. & R. Master Output controls. Output 775mV. Size 360×280×90mm. Supply 220-240v.
**Price £134.99 — £4.00 P&P**

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