AN ARGUS SPECIALIST PUBLICATION

electronics today

INTERNATIONAL DECEMBER 1987 £1.40

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WHAT YOU NEED & HOW IT WORKS
BUYING SECOND HAND

SWR METER

COMPUTERISED HEATING CONTROLLER

YOUR FREE COMPONENTS TO BUILD THE ETI DREAM MACHINE

AUDIO....COMPUTING....MUSIC....RADIO....ROBOTICS...

125

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NOV. 1987 VOL 16 No.11

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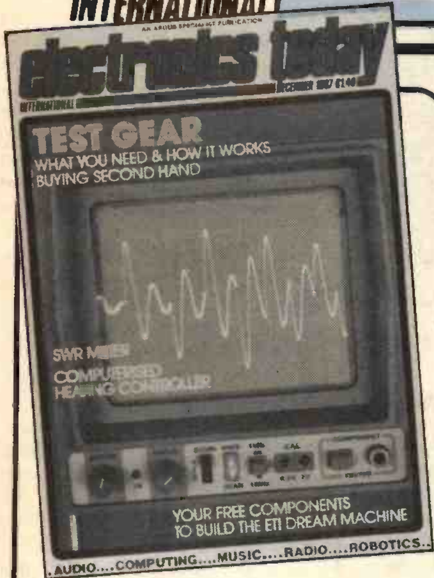

Cover oscilloscope courtesy of Henry's Audio Electronics

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FEATURES

PROJECTS

REGULARS

• **If you're still itching to get your hands on the TMS34010 graphics processor described in the April 1987 issue you may be interested to hear about a new design kit from Texas Instruments. It includes all you need to design a bit-mapped graphics system including a TMS34010 processor, a TMS34070 colour palette, an assembler/linker/simulator package and all the necessary data and user guides.**

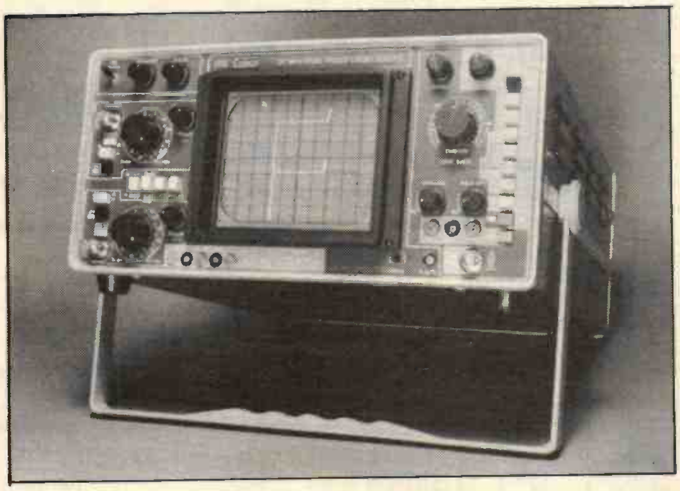
The kit costs £340 plus £2 postage plus VAT from Online Distribution Ltd, Melbourne House, Kingsway, Bedford MK42 9AZ. Tel: (0234) 217 915.

• The BBC is to change the frequency of its long-wave Radio 4 transmitters following a recent decision by the World Administrative Radio Conference that all long-wave stations should operate at 9kHz frequency spacings. The new Radio 4 frequency will be 200kHz (1500m) instead of 198kHz (1515m). The long-wave transmitters currently maintain a frequency stability of one part in 1011 or better (using the National Physical Laboratory's caesium standard) and are used by some industries as a reference source. Such companies are advised to check with their equipment suppliers or manufacturers so that modifications can be made to suit the new frequency.

• *Twits is the slang name for travelling wave tubes and if you're into twits you may be interested in a set of free literature which has just been made available by Ferranti. It includes specifications on travelling wave tubes and tube amplifiers for radar applications and can be obtained from the Professional Components Division, Ferranti Industrial Electronics Ltd, Dunsinane Avenue, Dundee DD2 3PN. Tel: (0382) 89311.*

• **Your mains driven clock or timer can be given a battery backup with the help of a new 50Hz crystal timebase kit from Electronics and Computer Workshop Ltd. It operates from any DC supply between 5 and 20 volts and uses a 3.2768Mhz crystal to ensure a stable output frequency. The kit costs £20.38 inclusive from ECW Ltd, Unit 1, Cromwell Centre, Stepfield, Witham, Essex CM8 3TH. Tel: (0376) 517 413.**

• *Industrial Automation Products is the title of a 200-page catalogue from Analog Devices which describes techniques and devices for data acquisition, signal conditioning, analysis and control. The catalogue includes design hints and a tutorial section on 'real-world IO' and is available free-of-charge. Contact Analog Devices, Station Avenue, Walton-on-Thames, Surrey KT12 1PF. Tel: (0932) 232 222.*



Hidden Depths Of 3-in-1 Scope

Crotech Instruments has launched a 25MHz dual-trace oscilloscope which incorporates a bench power supply and a dual component comparator.

The Model 3133 features a timebase range from 40ns/division to 200ms/division, a maximum vertical sensitivity of 2mV/division and a number of trace manipulation facilities including X-Y and addition or subtraction of channels.

Triggering is reliable up to 40MHz and a 10:1 timebase hold-off is provided to ensure reliable triggering on aperiodic and complex waveforms. An active TV trigger circuit is also included. The rise time is 14ns.

The built-in power supply provides outputs of +5V at 1A and ±12V at 200mA. The dual component comparator allows both active and passive components to be tested and can be used for circuit signature comparison.

The Crotech Model 3133 costs £319 plus VAT and comes with a two-year guarantee.

For further details contact Crotech Instruments Ltd, 2 Stephenson Road, St. Ives, Huntingdon, Cambridgeshire PE17 4WJ. Tel: (0480) 301 818.

Accurate Meter For The Milli-ohms

Startronic claims its latest milli-ohmeter is far more accurate than previous models.

Covering the range from 1 milli-ohm to 200 ohms it is accurate to better than ±0.1% yet uses a test current of only 5mA maximum.

The M210 has three automatically selected ranges and displays the results on a 3½ digit LCD. An over-range indication is provided for resistances above 199.9R. The unit is powered by a 9V PP3/MN1604 battery and includes an automatic shut-off to prevent the meter being left on for long periods by mistake.

Startronic expects the M210 to be used for checking motor and transformer windings, PCB tracks, switch and connector contacts and soldered connections. It can also be used in earth continuity testing to check for compliance with IEE wiring regulations.

The M210 costs £165 plus VAT complete with test leads and instructions.

Startronic (UK) Ltd, Beeching Road, Bexhill-on-Sea, East Sussex TN39 3LG. Tel: (0424) 214 291.

Testing Times For British Standards

Is your electrical equipment safe to use?

Of course it is, you say, it has a neat little label on it which says 'This appliance complies with the requirements of British Standard number. . .'

Unfortunately those reassuring little messages may not be all they appear. Any manufacturer can claim its products reach the required standard and slap on a label to say so.

No doubt companies will go on doing this but if they want their claims to carry real weight they can now turn to a newly-introduced testing service run by the British Standards Institution itself.

The service, called BSI Testing is based in Hemel Hempstead. In return for a suitable fee, manufacturers can have their products inspected in detail and a full report drawn up. Products which pass the tests will be allowed to carry the wording 'a sample of this product has been passed by BSI Testing as complying with the relevant British Standard (BS . . .). Report number . . . refers.'

The new service will be run alongside BSI's existing quality assurance programmes such as the well-known Kitemark standard. BSI Testing has been operating this and other programmes for over 25 years and is recognised both nationally and internationally as a leading test centre.

Further details of the new service can be obtained from Robin Dandy, Assistant Director of BSI Testing, on (0442) 230 442.

Microvitec Go For Laser Discs

Microvitec, best known as a manufacturer of colour computer monitors, has recently installed a laser videodisc cutting system which is says is the first of its type in the UK.

The system is manufactured by the Optical Disc Corporation of America and can produce videodisc masters for as little as £395 each compared with £2500 or more using other systems.

The Recordable Laser Videodiscs (RLVs) which result from this process are less robust than conventional videodiscs but are fully laservision compatible. They are 12in, single-sided and offer up to 36 minutes playing time or 5400 still frames.

Further details can be obtained from the Microvitec Laser Lab, Futures Way, Bolling Road, Bradford BD4 7TU. Tel: (0274) 734 944.

Manpower Prospects Show Increase

The latest quarterly survey of employment prospects by Manpower PLC shows a slight net increase in the number of electronics companies planning to take on more staff.

Only 4% of employers in the electronics and computer manufacturing industry are planning to lay-off staff compared with 7% in the last quarter and 6% a year ago. At the same time the number planning to increase their staff has risen from 29% to 30%.

If the percentage of companies planning to shed staff is subtracted from the number planning to increase staff, the net figure can be seen to have risen from 22% last quarter to 26% now. The net figure for the last quarter of 1986 was 23%.

Manpower specialises in providing temporary staff for a wide range of industries and carries out regular research on staffing requirements. The latest survey notes that the services sector still offers the best job prospects but that manufacturing (including electronics) is now running a close second. The public sector continues to offer much poorer job prospects by comparison.

Manpower PLC, Manpower House, 270-272 High Street, Slough SL1 1LJ. Tel: (0753) 73111.

Data Sockets For BT Phone Lines

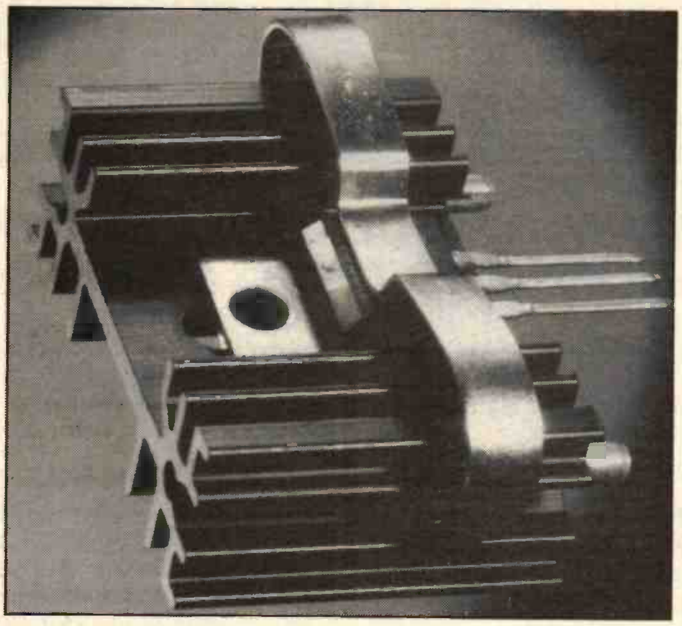
The familiar BT master sockets currently used on UK telephone installations will soon be replaced by a new type of multi-purpose connection unit.

As well as providing a socket for plug-in telephones the new wall boxes will include a terminal block for use with personal computers, facsimile machines Prestel, terminals and many other types of data and telecommunications equipment.

The units will be known by the initials NTE (Network Terminating Equipment) and have been designed by Astralux Dynamics to British Telecom's requirements. A detachable wiring module allows connecting leads to be made up at the work bench and simply clipped into the NTE when ready.

Astralux Dynamics has already begun production of the NTE units and expects them to be fitted to all new domestic and single-line business installations in the near future.

Astralux Dynamics Ltd, Red Barn Road, Brightingsea, Colchester, Essex C07 0SW. Tel: (0206) 302 571.



Choice Of Heatsinks For The Board

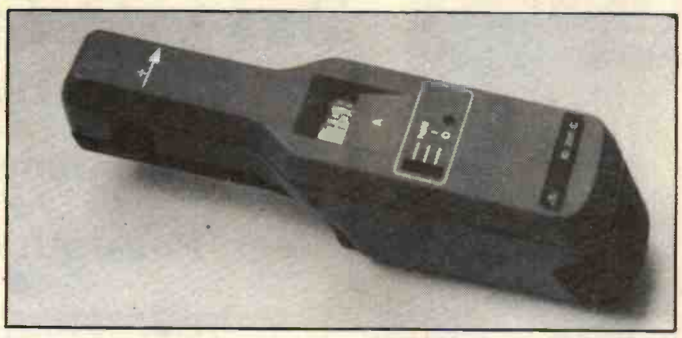
The latest heatsinks from Marston-Palmer can be soldered directly to PCBs and come in a wide range of sizes, profiles and component mounting options.

Known simply as the board-mounted range they offer thermal resistances from 7 to 12°C/W and can be supplied with or without solderable PCB pins. The three extrusion profiles vary in size from 34.5 x 12.5mm to 36.8 x 15mm and all are available in four standard lengths ranging from 25mm to 63mm.

The heatsinks can be supplied ready-drilled in a variety of patterns to suit standard semiconductor packages or undrilled so that components can be attached by means of a spring clip.

Prices range from about 28p to 56p each in quantities ot ten or more and a postage charge £2 is payable on small orders. All prices exclude VAT.

Marston Palmer Ltd, Wobaston Road, Fordhouses, Wolverhampton WV10 6QJ. Tel: (0902) 783 361.



Clamps Mean Amps For DC Too

Hartmann and Braun has introduced a clamp-type digital ammeter which measures DC currents.

Like conventional AC clamp meters it works without being directly connected to the circuit under test. The spring-loaded jaws are simply clipped around a conductor and the current is indicated on a 3½ digit liquid crystal display.

The ID 200C uses Hall effect sensors and measures currents up to 199.9A. The accuracy is to within ±0.5A up to 100A and ±1.5A at higher currents. The jaws will accept conductors up to 14mm diameter and a hold facility is included to allow measurements to be made in awkward places.

The meter will operate for up to 25 hours continuously on one alkaline 9V battery and has been designed to allow comfortable, single-handed operation. It weighs 200g and measures 46 x 51 x 175mm (1.8 x 2.0 x 6.9in).

The ID 200C costs £179.50 plus VAT and comes with a one year guarantee. It can be obtained from Alpha Electronics Ltd, Unit 5, Linstock Trading Estate, Wigan Road, Atherton, Manchester M29 0QA. Tel: (0942) 873 434.

- Axiom Electronics is distributing a data book which gives full technical details on the Sprague range of ICs. Its 750 pages cover linear devices, miltary CMOS, military driver ICs and a range of high voltage, high current and BiMOS power interface ICs. Applications circuits are included and the book is available free-of-charge from Axiom Electronics Ltd, Turnpike Road, Cressex Industrial Estate, High Wycombe, Buckinghamshire HP12 3NR. Tel: (0494) 461 616.
- **Five Star Connectors was set up three years ago as part of STC and aims to supply a wide range of connectors backed up by expert technical advice. The range extends from jack plugs to military-spec multipole connectors and everything is available ex-stock and with no minimum order charge. Full details are contained in a 216-page A4 catalogue which is available from Five Star Connectors. Edinburgh Way, Harlow, Essex CM20 2DF. Tel: (0279) 442 851.**
- Fast Fourier Transform (FFT) analysers are rapidly coming down in price and are now used in the assessment of brain waves, wow and flutter, transformer harmonics, horn quality, telephone filter performance and even for gear box analysis. A booklet covering many of these applications has been put together by Hakuto and is now available free on request. Contact Mr. D. Coffey, Hakuto International (UK) Ltd, 33-35 Eleanor Cross Road, Waltham Cross, Hertfordshire EN8 7LF. Tel: (0992) 769 090.
- *Texas Instruments has introduced a range of pin-compatible replacements for industry standard comparators offering up to 20 times less power consumption. The TLC339, 393, 3702 and 3704 are fabricated in LinCMOS technology and offer comparable performance to the LM339, 393 and so on, but with input current drains of 20μA per comparator maximum. For further information contact Richard Mann at Texas Instruments Ltd, Manton Lane, Bedford MK41 7PA. Tel: (0234) 63211.*
- **MathCAD runs on an IBM PC or compatible and allows the user to enter equations, display them with full notation and special symbols, calculate the results and then produce a printout with tables or graphs if required. The package costs £245 plus VAT but you can find out what it's capable of for free using the Mini MathCAD version. It does everything the full system does except that there are some restrictions on storage and printout. Mini Math CAD can be obtained from MathSoft International, FREEPOST, Tamworth, Staffordshire B79 7BR. Tel (0827) 86239.**

NEXT MONTH

AN ARGUS SPECIALIST PUBLICATION

electronics today INTERNATIONAL

FAT & FESTIVE, FULL OF FACILITATING FABRICATIONS AND FASCINATING FEATURES

Next month's ETI has 16 extra pages to keep you amused over the festive period. Each and every one is crammed with Christmas goodies of an electronic nature.

MUSIC POTPOURRI

There's a bumper collection of music circuits for all ETI readers intent on adding a little song to the festivities. Where else can you get envelopes, overdrives, cross-pans, Walsh functions and a silk purse, all in the same article?

NEW, IMPROVED...

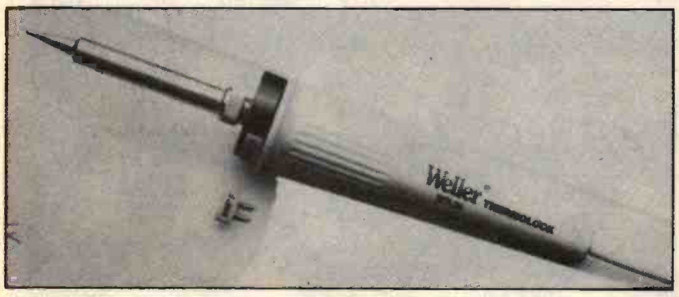
The ETI mains conditioner from the September 1986 issue has proved to be very popular with the computer and hi-fi owning populace. Now ETI brings you the improved version which not only does an even better job of cleaning up all the mains-borne grunge but shows you what's going on with lots of pretty lights as well.

MUCH MUCH MORE...

That's not all, of course. The January ETI also features the second parts of the Heating Management System and the Electronic Violet and several new projects to whet the appetite of your soldering iron. And there's the regulars too. Where would Christmas be without your monthly dose of news, reviews, diary, letters and ads from ETI?

The articles listed are all under way but unforseen circumstances may prevent publication.

JANUARY ETI — OUT DECEMBER 4th



A Hot Tip From Weller

The Thermolock soldering iron from Weller offers precise control of tip temperature thanks to a novel electronic key.

The temperature is set by plugging one of three temperature keys into a socket on the iron. Each key sets a different temperature (600°C, 700° or 800°C) and is laser trimmed for an accuracy of better than ±6°C.

The iron is rated at 42W and operates from a 24V DC supply. The element is controlled by a thyristor which operates in a zero-voltage switching arrangement, removing the risk of transients on the tip which might cause damage to static sensitive devices.

The Thermolock is designed for use with the ET series of soldering tips and is supplied with an ETA tip already fitted. A 700° temperature key is also supplied with each iron, the other two keys being sold as optional extras.

The Thermolock costs £42.50 plus VAT and postage and is available from Axiom Electronics, Turnpike Road, Cressex Estate, High Wycombe, Buckinghamshire HP12 3NR. Tel: (0494) 461 616.

Plessey And GEC To Go Halves

Plessey and GEC are to merge their international telecommunications businesses barely a year after a GEC take-over bid for Plessey was ruled out by the Monopolies Commission.

The 50-50 joint venture will produce a company with assets of £600 million and annual sales of more than £1.2 billion. It will take GEC and Plessey from their present positions as 10th and 12th largest companies in the world telecoms market up to 9th place — ahead of the Dutch giant Philips.

The merger was announced on October 1st although it was made clear that agreement still has to be reached on many of the details. However, it is almost certain that job losses will result since both companies are currently producing System X exchange equipment at separate plants. Concentrating this work would bring considerable economies, as was pointed out by the watchdog body Oftel during last year's takeover bid.

News of the merger came shortly after the publication of a major report on the telecommunications industry by the financial services company Alexanders Laing and Cruickshank. The report argues that demand for System X exchanges will wind down after 1990 and that companies involved in the traditional telecoms manufacturing areas of telephones and exchanges will face a fiercely competitive future.

The report also suggests that the future of public switching systems lies with the larger European companies and foresees joint ventures and co-operative agreements as the only means whereby UK companies can remain competitive.

The report is entitled *'Uncrossing the lines? Prospects for Telecommunication Operations & Equipment Manufacturing In The UK'.* It is available from Alexanders Laing and Cruickshank, Piercy House, 7 Copthall Avenue, London EC2R 7BE. Tel: 01-588 2800.

DIARY: DIARY: DIARY: DIARY: DIARY: DIARY: DIARY: DIARY:

Knowledge Based Systems in Government — November 4-5th
Gatwick Hilton, London. Contact Online at the address below.

Analogue IC Design — November 5th
The IEE, London. Tutorial lecture. Contact the IEE at the address below.

Reproduced Sound Conference — November 5-8th
Hydro Hotel, Windermere. Topics covered include acoustics, digital techniques, measurements and electro-acoustic music. Contact the Institute of Acoustics on 031-225 2143.

The Future Of The Personal/Home Computer — November 10th
The IEE, London. Lecture by Sir Clive Sinclair. Contact the IEE at the address below.

Electronic Message Systems — November 10-12th
Tara Hotel, London. Contact Online at the address below.

Computers in The City — November 17-19th
Barbican Exhibition Centre, London. Contact Online at the address below.

Electronic Displays — November 17-19th
Kensington Exhibition Centre, London. Contact Network Events at the address below.

Interact '87 — November 17-19th
Kensington Exhibition Centre, London. See June '87 ETI or contact Network Events at the address below.

COMPEC — November 17-20
Olympia, London. Contact Cahners at the address below.

Interactive '87 (Interactive video) — December 1-3rd
Metropole Exhibition Centre, Brighton. Contact PLF Communications on (0733) 60535.

System Security — December 1-2nd
Wembley Conference Centre, London. Contact Online at the address below.

Cellular and Mobile Communications — December 2-3rd
Wembley Conference Centre, London. Contact Online at the address below.

Satellite Communications — December 2-3rd
Wembley Conference Centre, London. Contact Online at the address below.

Cross Channel Cable Link — December 3rd
Lecture by G. Struthers (CEGB) at Gonville Hotel, Gonville Place, Cambridge. Contact Eastern Region IEEIE on (0603) 628321.

The UK Space Programme — December 7th
The IEE, London. Lecture by R. Gibson of the British National Space Centre. Contact the IEE at the address below.

British Engineering Supplies & Technology — January 18-21st
Olympia, London. Contact Mack-Brooks Exhibitions on (07072) 75641.

The Which Computer Show — January 19-22nd
NEC, Birmingham. Contact Cahners at the address below.

Electro-Optics And Laser UK — March 22-24th
NEC, Birmingham. Exhibition which runs alongside the Optics-Ecoosa '88 conference at the Birmingham Metropole Hotel. Contact Cahners at the address below.

Computing in the Next Generation — March 25-27th
Annual conference of the British Computer Society's Young Professionals Group. Julia Allen on 01-637 0471 for the venue and other details.

HF Radio Systems And Techniques — April 11-13th
The IEE, London. Conference organised by the IEE and the Institute of Mathematics and its Applications. Contact the IEE at the address below.

ATE 1988 (Automatic Testing and Test Instrumentation) — April 26-28th
Metropole Exhibition Centre, Brighton. Contact Network Events at the address below.

MILTEST 1988 (Military Testing Equipment) — April 26-28th
Olympia, London. Contact Network Events at the address below.

Addresses:
British Kinematograph Sound and Television Society, 547-549 Victoria House, Vernon Place, London WC1B 4DJ. Tel: 01-242 8400.

Cahners Exhibitions Ltd, Chatsworth House, 59 London Road, Twickenham TW1 3SZ. Tel: 01-891 5051.

Institution of Electrical Engineers, Savoy Place, London WC2 0BL. Tel: 01-240 1871.

Network Events Ltd, Printers Mews, Market Hill, Buckingham MK18 1JX. Tel: (0280) 815 226.

Online International Ltd., Pinner Green House, Ash Hill Drive, Pinner, HA5 2AE. Tel: 01-868 4466.

READ/WRITE

Success On The Brain

Thanks for publishing an EEG monitor circuit which actually looks as though it may work! I haven't finished building it yet so I don't know for sure but I have worked on two designs from other sources in the past which were only good for soldering practice as they were totally useless in operation.

Thanks for a very interesting magazine with a good mix of theory and practice. Even though all is not immediately relevant, I find myself frequently referring to back issues, especially as new developments such as surface mounted devices and PALs become more common.

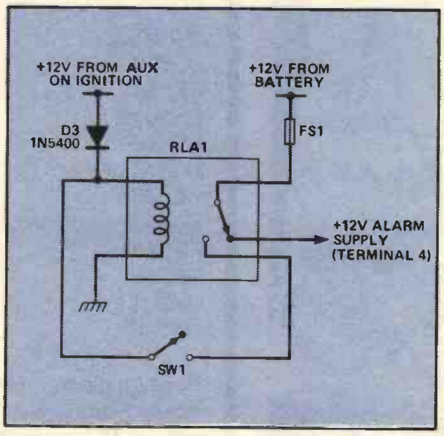
Keep up the good work.
Hugh Dogherty
Castlewellan, Co. Down.

Alarming Extras

Many thanks for the excellent Car Alarm from Bob Noyes in the August ETI.

To make the alarm simpler to operate (and harder to forget about) how about the following modificaton to replace key switch SW1 in the original.

With this setup the alarm will be automatically armed when the ignition key is turned to the off position and disabled in any other position. If the override switch SW1 is closed



when the alarm is off then the alarm will not be activated when the ignition is turned off — useful for stopping at filling stations and so forth.

The relay only consumes power when the ignition is on. D3 is included to prevent auxilliary circuits from being powered when the alarm is overridden.

Adam Hill
Tile Cross, Birmingham.

Thanks for a useful addition to a popular project.

Expensive PCBs?

What an excellent series John Yau's MIDI Master Keyboard was. I have now written to Mr. Yau to order the EPROM and offered a couple of suggestions for possible additions and accessories for the machine.

I enjoy the magazine very much. I think it is the most 'down to earth' of those currently available (no pun intended!).

It's a pity, then, that the PCB Service is relatively expensive compared with some of the opposition. Yes, I know, you did say a few months back that you were having difficulty in getting the PCBs produced economically. But still . . .

George Metters
Stoke Gabriel, Devon.

Any constructive criticisms or additions to any project are always welcome. If any reader develops a published project (say, you write some extra code for the MIDI Master Keyboard EPROM) we shall be most interested in hearing of it and may well want to publish the additions in ETI.

The PCBs offered through the ETI PCB Service are a little on the expensive side because they are produced largely on a one-off basis. We do not have the facilities to have large batches of PCBs made for each project to keep the prices low. However, the quality of boards produced is extremely good and the turnaround is now between a week and a fortnight — a far cry from the troubled days of a year ago.

Cheap PCBs

After years of thrashing out PCB transparent artworks from magazines using rub-down transfers (and filling in the cracks afterwards) I have stumbled across an incredibly simple method of producing near-perfect artworks from the published foil patterns.

Ordinary drafting film is placed in the cartridge paper tray of an ordinary photocopier (not the old 'wet' type, though) and the foil pattern is placed on the glass in the normal way.

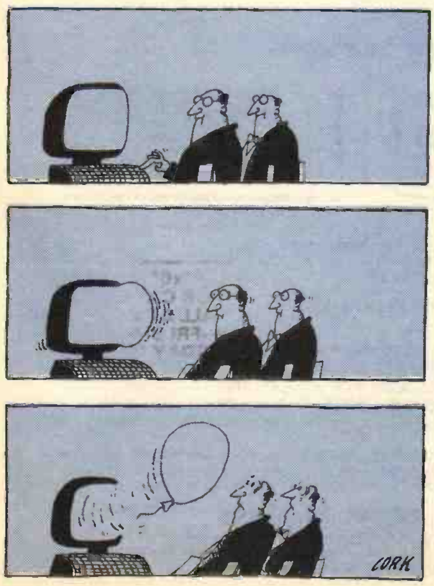
The resulting copy is very good. It's a little 'dusty' but the dust doesn't print through onto the board in the UV light box. The copy is fixed using an aerosol clear laquer (such as RS 556-222) which protects and improves contrast. Et voila! — a positive transparency which is as good as the published foil pattern.

Any blobs on the copy can be corrected by scraping them off with a sharp knife before laquering.

Rolf Startin
Hammersmith, London.

Mr. Startin sent us samples of each stage of the process and it must be said that the quality of the final PCB is excellent. The drafting film can be bought at any art shop or alternatively you can purchase celluloid film expecially for photocopying. Now you've no excuse to avoid making those ETI projects!

CORK

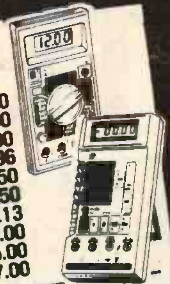


This is page nine. You have just read eight pages of information, wit and satire in the form of the preceding cover, contents, news and ads. Surely there was something among that lot which calls out for comment or correction. I'll give you until the end of the magazine and then I expect you to put pen to paper. Write to:

Electronics Today International
1 Golden Square
London W1R 3AB.

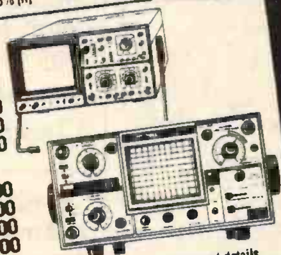
TEST INSTRUMENTS
UK's LARGEST IN-STOCK RANGE

DIGITAL MULTIMETERS
(All 3½ Digit LCD, *4½ Digit, °With Case, †Case £3.91)
(R = Rotary Pb = Push Button S = Slide)



- KT305 (°) 26 range plus Hfe test 10A AC/DC 20meg buzz 0.5% (R) £37.00
- KT10 (°) 31 range incl. 5 range CAP 10A AC/DC 20meg buzz 0.5% (R) £36.00
- KT5005 (°) 4½ digit 28 range plus Hfe 10A AC/DC 20meg 0.07% (PB) £83.00
- KD508 (†) 15 range AC/DC volts 0.2A DC 2 meg (S) £19.96
- KD578 (†) 20 range 10A AC/DC auto range display hold 0.8% (R) £34.50
- 6010 (†) 28 range 10A AC/DC 20 meg 0.25% (PB) £33.50
- 5010EC (†) 34 range incl. CAP Hfe temp etc 0.25% (R) £52.13
- M3530 (°) 28 range incl. 5 range CAP plus Hfe 10A AC/DC 0.5 (R) £53.00
- M3800 (°) 30 range plus Hfe 20A AC/DC 20 meg 0.5% (R) £35.00
- M3650 (°) 30 range incl. Hfe CAP freq. count. 20A AC/DC 0.3% (R) £57.00

SCOPES (★with probes)



HAMEG - all with component testers
- ★203/6 Dual 20MHZ £314.00
- 204/2 Dual 20MHZ + sweep delay £418.00
- ★205/2 Dual 20MHZ + digital store £527.00
- 605 Dual 60MHZ + sweep delay £583.00

HUNG CHANG (6" FLAT screen 615 3¾ CRT)
- ★620 Dual 20MHZ + comp test £295.00
- ★635 Dual 35MHZ sweep delay £399.00
- ★650 Dual 50MHZ sweep delay £579.00
- ★615 Dual 15MHZ Batt/mains £399.00

Also stockists for Hitachi and Crotech. Logic analysers LA160. Ask for prices and details.
Scope Add ons. Storage TD201, 8CH adaptor OM 358.

POCKET INSTRUMENTS (★with case. + £3.91)

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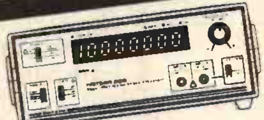

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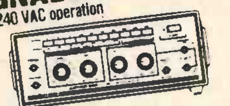

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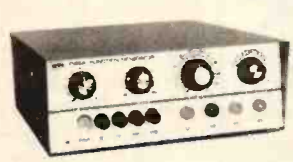

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TEST EQUIPMENT

Keith Brindley takes a look at the different types of test equipment available and assesses their usefulness to the home constructor.

There are three main areas in which test equipment is used: design and development; manufacture and quality assurance; service and repair. These three areas follow the stages of a product's life, from drawing-board to manufacture to use and ultimately to the scrap heap.

The complexity of the test equipment used at each stage varies enormously. For example, test equipment used at manufacture and quality assurance stages is typically large, complex and pricey — at these stages each appliance is affected by the equipment so the overall cost per appliance is quite small. Also, the better the appliance is made, the less likely it is to break down and require servicing. Size too is usually of little significance here.

Test equipment used for service and repair is a different matter. A service engineer complete with Ford Escort 1.3GL hasn't got a lot of room to spare in his travels, so size is of prime importance. Cost is a high priority, too: the equipment must be sufficient to allow effective service yet be cheap enough for use by all the company's service engineers.

In the development lab test equipment has also to be cost effective, although pure cost is not usually such an important criterion. Of particular concern is that it must be of sufficient complexity to allow the engineer to design and develop the appliance.

For the home constructor, the question of what test equipment to buy is often a knotty one. The home constructor uses test equipment in all three areas, developing, manufacturing and servicing a project from beginning to end. But as the project is not for sale, profit is not a motivating concern, so test equipment can only be financed from the constructor's own pocket. Obviously, the home constructor's test equipment must be as versatile and as cheap as possible.

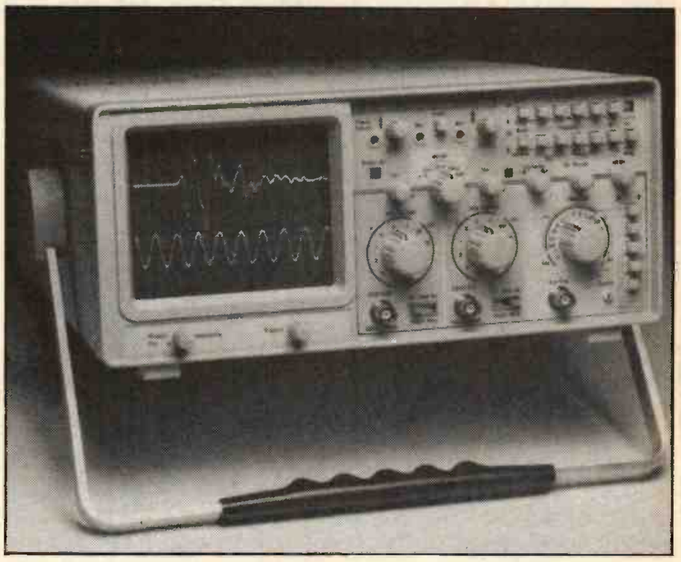
The Ins And Outs Of Test Equipment

But what does test equipment actually do? In simple terms, it merely allows an observer to see how the appliance is operating. Once the observer has done this, a decision can be made to change appliance operation — but this is a human decision (with all except the most expensive automatic test equipment). Test equipment merely aids the observer.

Test equipment falls into two basic categories:

- equipment which provides a signal of some description to the appliance under test, and
- equipment which monitors and displays the operation of the appliance under test.

The first category includes signal sources, waveform generators and even power supplies. The second category includes meters, oscilloscopes, analysers, etc. There is inevitably overlap between the two categories and some equipment may comprise parts from both, for example logic analysers which feature a digital pattern signal generator together with an oscilloscope-type display.



Before the introduction of the microprocessor, testing an appliance was often as simple as applying a suitable signal at the appliance's input and observing the signals obtained at each stage. Often the only test equipment required was an audio signal source and an AVO meter, maybe an oscilloscope. In many instances today, analogue or digital, this is still the case. When the microprocessor came along it brought with it the requirement to observe many signals simultaneously. An oscilloscope isn't capable of displaying more than a couple of signals at any one time — hence the development of the logic analyser.

The test equipment you need therefore depends almost totally on the projects you build. The more complex they area, the more complex (and costly) the test equipment you are likely to need.

Signal Sources

So what types of test equipment are available, and how do they function? We'll start with the first category we identified: equipment which provides a signal input to the appliance under test.

More by default than by design, signal sources are generally grouped into audio frequency sources (normally called low frequency oscillators) and radio frequency sources (normally called signal generators). There's no logical reason for this and not all manufacturers follow the convention.

This description of signal sources caters only for analogue appliances. Logic pattern generators or word generators are the digital equivalents of the analogue signal source, producing preselected serial or parallel data at a preselected speed.

As far as low frequency oscillators (LFOs) are concerned, most cover the frequency range 1Hz to about 1MHz in a number of switched ranges. Accuracy and stability depend mainly on the method used to produce the signal. Traditionally, harmonic oscillators such as the Wien bridge, the phase shift, or the bridged-T circuit (Fig.1) are used in cheap and cheerful LFOs, and these can produce distortion as low as only 0.001 per cent. The drawback is that stability is not particularly good and some drift of signal frequency can be expected. Another disadvantage is the limited range over which a harmonic oscillator can be tuned (about 3:1), so a lot of capacitor/resistor switching has to be done to produce a large overall output frequency range.

Another fairly cheap method of producing a signal is a relaxation oscillator, for example a stable multivibrator familiar to most home constructors. The most common relaxation design is the function generator shown in Fig.2 which has the advantage that an external voltage can be used to control the generated frequency. This means that a second oscillator can be used to sweep the function generator's output signal frequency over a preselected range — useful when testing some appliances. Frequency ranges of between about 0.01Hz to 2MHz are common, but although the frequency stability can be very precise the distortion is high because any sinewave output is only approximated from the triangular wave of the integrator provided. Typical distortion figures are 1 to 2 per cent. Provided this distortion figure is not a problem, the cheapness and versatility of function generators probably makes them the best type of signal source for the home constructor.

It is also possible to obtain digital LFOs which create an analogue waveform from digital information stored in a ROM. The information is converted to an analogue signal by a DAC. Stability of the signal output is usually pretty good because the stored information is read out on accurate, quartz-locked clock pulses and the distortion depends on the number of quantisation levels (the number of bits in each stored word or information) LFOs like this are usually too expensive for the home constructor but are worth bearing in mind.

RF signal generators can be made with harmonic oscillators in the same way that cheap and reasonable quality LFOs can. The two oscillators commonly used are the Hartley and the Colpitts (Fig.3). Again, limited tuning ranges mean that a lot of switching is needed to get a wide overall range and again, frequency stability is not good.

One way of beating the limited tuning range problem is by mixing the variable frequency oscillator's output with that of a fixed frequency oscillator, as in Fig.4. These heterodyne oscillators are common but the frequency stability is not improved because it still depends on the stability of the variable frequency harmonic oscillator.

Most more expensive signal generators use the phase-locked loop principle, sometimes called the synthesiser method. In this type of signal generator a fixed frequency and highly stable oscillator (usually a crystal reference) is used, so stability is excellent. A detecting circuit (Fig.5) compares the phase of this oscillation with the phase of the signal from a voltage-controlled oscillator after it has passed through a variable divider circuit, while the voltage-controlled oscillator's control voltage is supplied by the phase detector. The feedback loop formed by this phase-locking system stabilises the output signal to a frequency equal to the reference oscillator frequency multiplied by the division ratio of the divider circuit, so an extremely accurate and well defined output signal results.

Whatever your choice of signal source, make sure it is capable of doing whatever you think it will need to do now and in the future. For instance, if you can't afford a source with built-in sweep facilities, buy one with inputs for voltage control of frequency so you can cobble together a simple oscillator to give you the desired sweep.

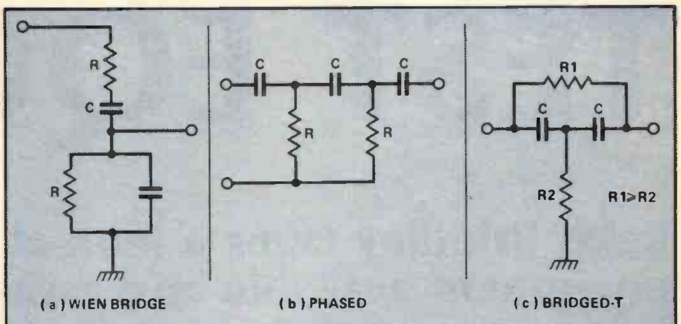


Fig.1 Typical low frequency harmonic oscillators.

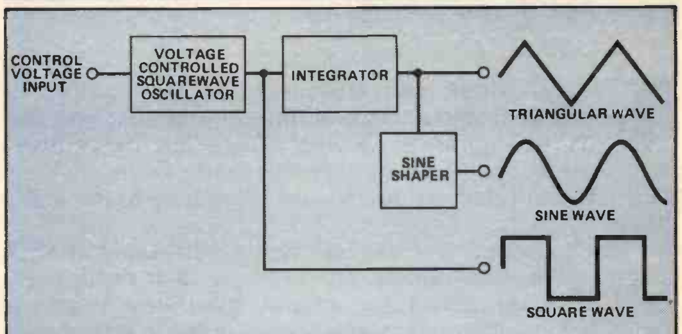


Fig.2 Block diagram of a function generator.

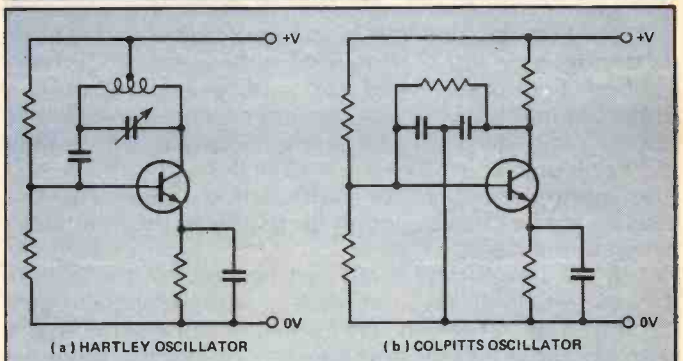


Fig.3 Typical RF harmonic oscillators.

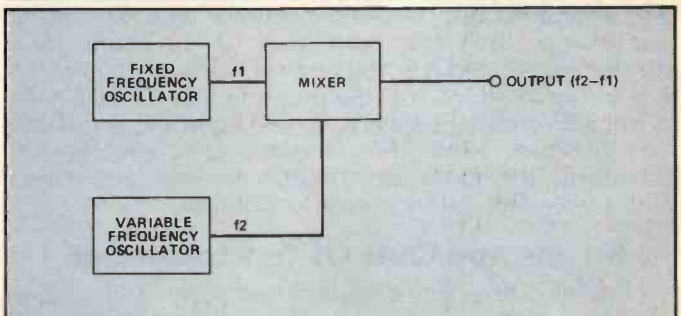


Fig.4 Block diagram of a heterodyne oscillator.

Meters

Until the last five years or so most meters were analogue with a moving coil or similar display device, but recent developments in segmented LED and LCD displays have allowed fairly cheap digital meters to be made.

The moving-coil movement used in analogue meters is only capable of displaying a value of current or voltage between about 10μA to 1mA or 50μV to 5V but with parallel and series resistance networks (shunts and multipliers) other voltages and currents may be measured.

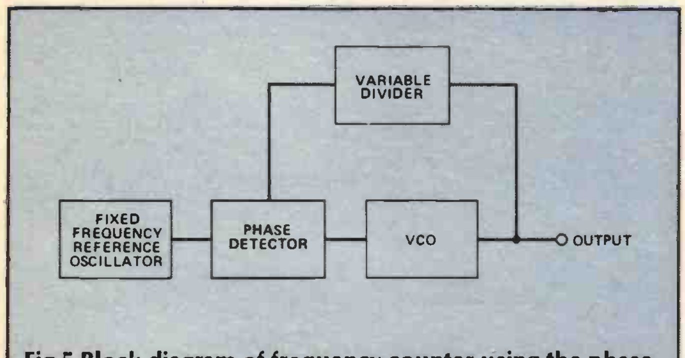


Fig.5 Block diagram of frequency counter using the phase-lock loop or synthesiser principle.

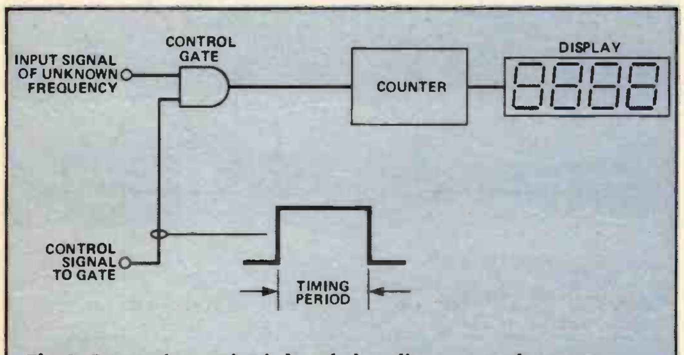


Fig.6 Operating principle of the direct gated counter.

Most moving-coil movements are used in a simple switching arrangement with resistors to give the common-or-garden multimeter capable of measuring a complete range of voltages and currents. A local power source is used to create a current through an external circuit enabling the multimeter to measure resistances as well. The famous Avometer is probably the best known example.

One problem with a basic moving-coil multimeter is its inherent insensitivity. A typical rating is 20,000 ohms per volt, which means that on a 5 volt range the multimeter's resistance to current is 20,000 times 5 which is 100,000 ohms. If the impedance of the circuit being monitored is high the meter's resistance may load the circuit and affect the overall impedance, so producing an inaccurate reading. As a general rule-of-thumb, the meter's resistance should be around ten times the impedance of the monitored circuit to ensure a reasonably accurate reading.

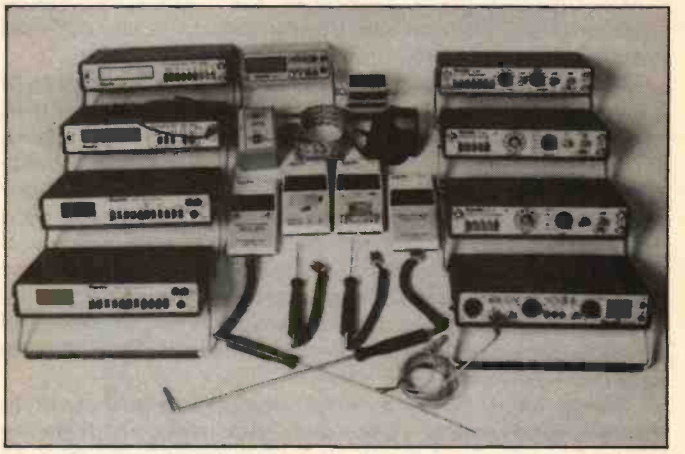
In some instances it will be impossible to ensure this ten times rule and in others you won't know the monitored circuit's impedance, so you won't know if the meter is loading it. Fortunately there is a way round this: take readings of the voltage on two of the meter's voltage ranges. If the monitored circuit's impedance is high enough to cause meter loading, the two readings will differ substantially.

If loading has occurred any reading displayed by the meter is inaccurate but the actual voltage in most instances can be calculated from the expression:

$$V=\frac{E_1E_2(R2-R1)}{E_1R2-E_2R1}$$

where V=the true voltage, E_1=the meter reading on the first range setting, E_2=the meter reading on the second range, R1=the input resistance of the meter on the first range setting, and R2=the input resistance of the meter on the second range setting.

Another way round the loading problem is to use an amplifier which has an extremely high input impedance as a buffer on the multimeter input. FET amplifiers and op-amps are ideal for this purpose.



Digital multimeters don't usually have this loading problem because their input stages normally include a high impedance input amplifier (around 10 megohm). So, on the face of it, a digital multimeter is the ideal. They are fairly cheap — some versions are much cheaper than analogue multimeters — and extremely accurate (analogue meters at best are only about ± 1% accurate due to the limitations of the mechanical movement). However, a digital readout is not always the most convenient since it is quite easy to mis-read and any changes of input voltage (even quite slow changes) can give confusing displays.

For the home constructor, though, a meter is a necessity. If you can only afford one, my advice is to buy as good an analogue meter as possible. If you can afford two, get a digital meter as well.

Counters

Meters operate in only one dimension: they measure and display, say, a voltage, at any one instant in time. The second dimension of time can be incorporated into a measurement in a number of ways, one of which is with test equipment loosely classified as counters, more correctly universal counter timers (UCTs).

UCTs are used to measure occurrences over a specified time, so a UCT could be used to measure the number of cycles arriving each second, which is to say that it can be used to measure frequency. Or it could be used to measure the time between two physically separate events in seconds. Further, it could be used simply to count the number of events occurring. Because of this, UCTs are often lumped together under the title frequency, time and event counters.

Figure 6 shows a signal being gated before it is fed to a standard digital counter and display. The control gate is opened by a pulse of defined period, so the result displayed is simply the number of cycles occurring during that period. If the period is exactly one second, the result will be in Hertz. This is known as the direct gated counter principle. Different gating periods can be used to give different measurement ranges.

It shouldn't take an Einstein to work out that the gating period is critical — if the period is 5% out then the displayed result will be 5% out, too. The gating periods of a UCT are therefore obtained by dividing down the output signal of a stable high frequency, crystal-controlled reference oscillator and the user should always choose the longest gating period possible to ensure highest accuracies. But even crystal oscillators can vary with temperature and ageing, so for highest accuracy some UCTs use temperature compensated crystal oscillators (TCXOs) or even oven controlled crystal oscillators (OCXOs). Most UCTs will have provision for the user to apply a standard reference frequency, too, such as those broadcast by international standards bodies.

For most frequency measurements, the direct gated counter is ideal but for low frequencies the gating period has to be so long that it becomes impracticable.

An alternative is the reciprocating gated counter in which the gate is opened for the period of the input signal itself rather than for a predetermined period. When the gate is open the output of a reference oscillator is passed to the counting circuits. If the input frequency is, say, 1Hz, the gate will open for alternate 0.5s half cycles and with a reference oscillator frequency of 2MHz a total of 1,000,000 pulses will be counted during each gate period. This figure is passed to an arithmetic unit which calculates the reciprocal of 1,000,000 and displays the result. The answer, of course, is 0.000001MHz which is 1Hz.

Some UCTs use the phase-lock loop principle to measure and display a low frequency input, multiplying the frequency of the input signal before gating and then moving the decimal point on the display to restore the original figure.

Most UCTs aren't formed by just one of these principles but are a combination of two or more. Sometimes prescalers may be used to allow the measurement of extremely high frequency signals by first dividing down the signal so that it is within the range measurable by the equipment. Extremely high frequency signals can also be heterodyned down to be measured by the UCT.

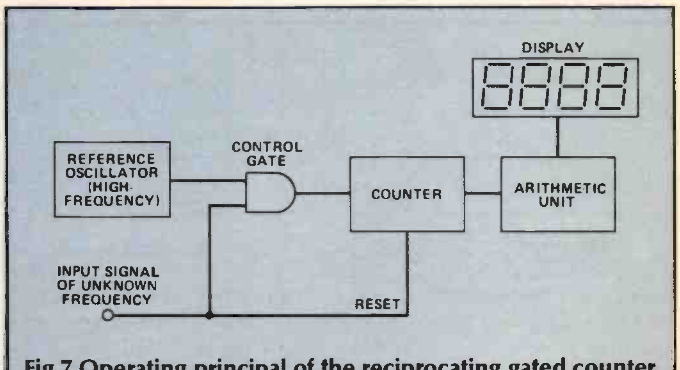


Fig.7 Operating principal of the reciprocating gated counter.

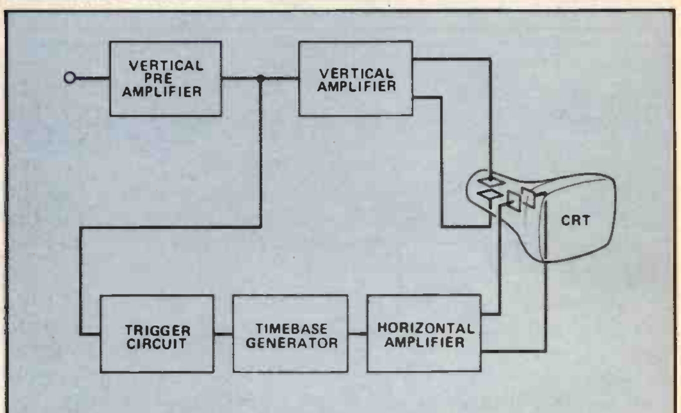


Fig.8 Block diagram of a basic oscilloscope.

Cathode Ray Tube Displays

Most well known of all CRT display test equipment is the oscilloscope and it's probably the most useful piece of test equipment anyone can have. Given some basic limitations it can even be used to measure voltage, frequency and time and so in many applications can be used instead of a multimeter and UCT. But that is not its real power because it is capable of displaying much more than the simpler test equipment can do.

The oscilloscope is a further example of test equipment which measures in two dimensions. However, the 'scope's CRT screen display is a graph of voltage against time, so what you see on the screen is an actual picture of what's happening in the circuit being monitored.

The representation of a signal in graphical form on the CRT screen is called a trace and oscilloscopes usually have one (single-trace) or two (dual-trace) circuits within them capable of doing it. A dual-trace 'scope can display two signals from the circuit under test almost simultaneously — but not quite simultaneously. In a dual-trace 'scope a single electron beam is shared by both traces, so the best the 'scope can do is display one signal, then the other, then return to the first, and so on. This normally occurs so rapidly that eye persistence means you can't tell the switching is happening. Some very expensive oscilloscopes have two separate electron beams but they are normally well out of the home constructor's price range and need no further mention here.

A block diagram of an oscilloscope is shown in Fig.8. Vertical amplifiers raise the input signal level to the voltage required by the vertical deflection plates of the CRT. Similarly a horizontal amplifier amplifies the timebase generator's output to the level required by the horizontal deflection plates. By varying the gains of the vertical amplifiers and by generating varying lengths of timebases, many different amplitudes and frequencies of input signal may be represented on screen.

The basic or real-time oscilloscope can only display repetitive or periodic waveforms. A number of oscilloscopes are non-real-time and can display non-repetitive waveforms. The most well known is the digital storage oscilloscope which captures and stores a single occurrence of an input signal over a given time. The signal is stored as digital information in RAM and then displayed repetitively on the screen. Storage 'scopes are more expensive than basic versions so the user has to decide whether the ability to view non-repetitive waveforms is worth the difference. In more than 99% of oscilloscope applications the viewed waveform will be periodic, so perhaps that helps you to make up your mind.

So what makes a good oscilloscope? First, bandwidth is important. Like any electronic system, the oscilloscope only passes a limited range of frequency components and those outside the bandwidth range are drastically reduced in amplitude. Obviously, the greater the oscilloscope's bandwidth, the greater the range of frequencies which can be represented on screen: common bandwidths are 10 to 20MHz.

Also important is the range of vertical amplifications. The greater the amplification, the smaller the signal that can be represented on screen. Oscilloscope screen displays are marked in a grid of centimetre square divisions known as the graticule. Amplification factors are usually denoted in volts/division or volts/centimetre. Typical amplification factor ranges are from about 10 millivolts/div to 5 volts/div but the better the 'scope, the greater the range.

So, do you need an oscilloscope for general-purpose, home constructor project building? As long as your project works first time without hiccups, a 'scope is not necessary. But if it doesn't work first time where do you start to fault-find without a 'scope? Ask any engineer what the most important piece of test equipment is — the answer is bound to be an oscilloscope. Buy one if you can afford it.

Logic Analysers

The oscilloscope is ideal for monitoring most analogue and some digital appliances but many digital appliances have buses of 8, 16, or even 32 bits. Only two signals (occasionally four) can be represented on the screen at any one measurement with an oscilloscope, so for this application it's pretty useless. A more specialised test instrument using the oscilloscope principle is the logic analyser.

In simple terms it is a multi-trace digital storage oscilloscope combined with a digital word generator. But it really is much more powerful than that because it's a microprocessor-based device and hence is software-controlled. Whether a logic analyser needs to be in the home constructor's test equipment list is arguable, but it's worth knowing what they're capable of if only for reference.

Logic analysers are usually microprocessor-independent, which means they can be used to monitor systems built around a wide range of microprocessors. To interface between the logic analyser and a particular system you will need interface modules, often nicknamed pods (personality option devices!). A pod is microprocessor-specific so it can be used only to monitor signals within a particular microprocessor's system — a Z80-based pod couldn't be used to interface the logic analyser with an 8085-based system. Sometimes the pods are separate devices, but they can be integral to the logic analyser on, say, a plug-in card. Used with a pod, the general-purpose logic analyser becomes known as a composite logic analyser.

Logic analysers are used in three main operating modes:

- timing analysis — in which the analyser is used very much as an oscilloscope, monitoring signals immediately before and after a particular trigger point. Signals are displayed on the CRT screen but as logic levels against time (unlike the oscilloscope's voltage against time display). So-called glitches in system operation can usually be spotted. The internal word generation functions of the analyser may be used to create the trigger point.
- state analysis — rather than watching logic levels to detect glitches, state analysis presents system operation on-screen as machine code in groups of zeros and ones in binary form. Often, a feature of state analysis is that the machine code is reverse-assembled back into the assembly mnemonics of the system and displayed as such on-screen. This feature is known as disassembly.
- performance analysis — in which the microprocessor system's general software performance is monitored by the analyser. Displays in the form of graphs, histograms, etc may be used to show factors such as system address usage, program statement execution times, etc.

Using a logic analyser is rather like photographing using a zoom lens. First you use the widest angle on the lens (performance analysis) to see how the overall system operates. Then you zoom in closer (state analysis) to see step-by-step program operation. Finally, you zoom right in for a close-up (timing analysis) to look at the actual circuit signals.

ETI

SECOND TIME AROUND

Julian Nolan shows how to pick up a bargain at the local auctions and equip your workshop without selling your house.

The total world market for test equipment has been estimated at $5000 million annually, the UK accounting for over £270 million of this. Even when the defence market and indirect sales for export are taken away, the British market for test and measurement equipment is still worth an estimated £40 million per annum. Taking this over nine years and assuming the £40 million to be at least static, this implies there is approximately £350 million worth of test equipment in British industry at the present time.

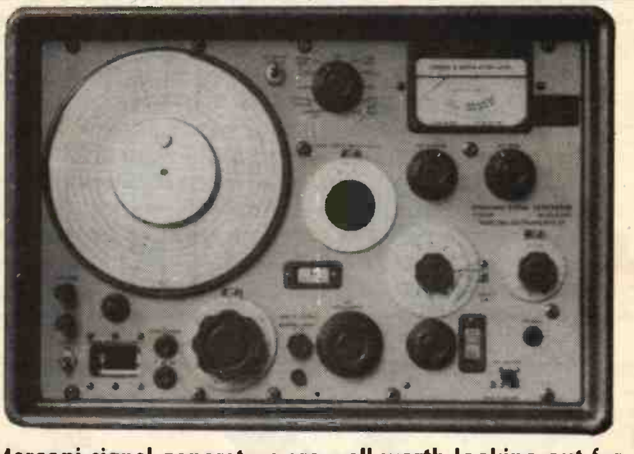
Estimates show that 15% of this equipment is updated yearly. Currently most manufacturers change their equipment when it is around 7-10 years old but this is gradually being reduced and a replacement period of 3-7 years is expected in the future.

The equipment being disposed of is normally either sold at auction or direct to the appropriate parties. Being only several years old much of it retains a high percentage of its original value and is outside the reach of most amateurs. However, a proportion of the equipment is older or of lower original cost and because of this its secondhand value is lower. This is the range covered by this article.

There are many disadvantages and advantages associated with buying secondhand test equipment. In almost all cases the specification of second user equipment will be higher than that of new equipment of the same price and the quality of construction will usually be higher too. There are some instruments which are of only average constructional quality and these may prove unreliable but with well-constructed instruments of reasonable age and condition there is every chance the reliability will equal that of new equipment manufactured to sell at the same price.

The size and weight of older instruments can be considerably greater than that of comparable instruments manufactured today. This applies particularly to scopes and signal generators but if portability is not essential some relatively old but very good equipment can be obtained quite cheaply.

The obvious points to check are that all the functions work correctly and that the overall physical condition of the instrument is good. Don't be content with checking just the principal ranges and functions — check everything. If a few of the functions don't work correctly it implies that the previous owners weren't too fussy about looking after the instrument. Conversely, an instrument which works correctly in every mode — even those which don't get used too often — is more likely to have been well looked after and regularly serviced.



Marconi signal generators are well worth looking out for. This TF144H 1okHz-70MHz AM RF generator costs about £90

As regards physical condition, pay particular attention to the state of the front panel. If it is scratched and dented the instrument has obviously received a lot of use and this will be reflected in the state of the electrical circuitry. Dents and scratches in the side and top panels are less of a guide because most instruments pick up slight damage here through being stacked.

The innards should be reasonably dust-free and any vents or cooling ducts should be unobstructed. An instrument which has been operated for any period of time with clogged-up cooling vents may well have suffered general or localised overheating with a consequent reduction in reliability. This is particularly true of fan-cooled instruments. Check all the PCBs and components for burn marks and examine all the mechanical components such as switches and connectors. Dirty contacts can be cleaned but excessive wear will mean replacement and some complex switches are very expensive.

Another factor which should be taken into account is the type of active circuitry employed — valve, discrete semiconductor or IC. Many instruments manufactured before 1970 use valves and while these are likely to be less reliable than instruments using semiconductor devices they are still worthy of consideration. The deciding factors will probably be the quality of the particular instrument and your own familiarity with valve circuitry. A well-constructed valve instrument from a reputable manufacturer will be scarcely less reliable than its modern semiconductor counterpart and if you know enough about valves to be able to service it properly there should be no problems.

Much the same can be said about instruments using discrete semiconductors. Some surprisingly complex instruments were built in the late 1960s using individual transistors throughout and while many of them are highly reliable they need to be checked carefully before purchase. Provided the instrument is made by a reputable company, is in good physical condition and works correctly in all modes of operation you should not go far wrong.

With all second-hand test equipment it is important to check that a service manual is either provided or is readily available. Fault-finding will be more or less impossible on many instruments without one and you will also need it in order to calibrate the instrument correctly. This is important because there is no point in buying high specification second-hand equipment if you are not going to keep it up to scratch. You might just as well spend your money on new equipment with a lower specification.

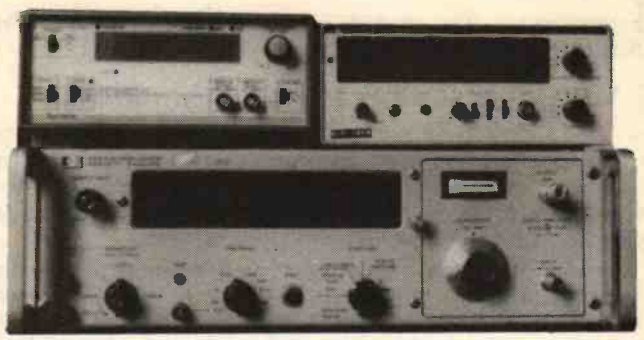
Oscilloscopes

Many electronics enthusiasts purchase a second-hand oscilloscope because they cannot afford a new one but even if you have a reasonable amount of money to spend you may still find that a used scope is a good buy. For example, a comparatively recent model like the Telequipment D83 (dual-trace, 50MHz bandwidth, delayed sweep, etc) can be purchased second-hand for only a fraction more than you would pay for a modern dual-trace 20MHz oscilloscope with only basic facilities. At the same time it should be borne in mind that oscilloscopes are complex instruments and spares such as CRTs and mains transformers may be difficult to obtain for some older models. The points mentioned in the following paragraphs should be checked carefully before buying any non-guaranteed oscilloscope.

The trace intensity should be such that the trace is clearly visible at the oscilloscope's fastest sweep speed on a triggered waveform of appropriate frequency. The intensity will naturally be better on scopes which use a higher accelerating potential but even on 2kV designs the trace should still be visible under these conditions. A faint or poorly-defined trace indicates either that the oscilloscope is incorrectly set-up or that the tube is reaching the end of its life. An oscilloscope in this condition should be avoided unless you are certain it can be repaired at a reasonable cost. It is also best to ignore any oscilloscope which has suffered screen-burn to such an extent that there are brownish-black points or lines on the tube face.

Digital storage oscilloscopes still command very high prices on the second-hand market but tube storage designs can be obtained for upwards of £100. Unfortunately storage tubes have a comparatively short life and can be very expensive to replace, some costing well over £700. On models such as the Tektronix 564 the tube life can be as little as two years and as these scopes are now around twenty years old they must be checked scrupulously before purchase. A worn tube will usually have a storage capacity which is only a fraction of the intended upper frequency and may also suffer from excessive flooding of the screen and a generally poor and ill-defined trace. All in all, it is best to avoid tube storage oscilloscopes unless they are offered with a comprehensive guarantee.

Some high-performance oscilloscopes are sold as a mainframe containing only the tube, the power supply and some control circuitry. The timebase and pre-amplifier circuits are supplied as plug-in modules, allowing the specification and functions to be changed as required. These modules may or may not be included in the price of a second-hand instrument and this should be checked before purchasing because a full set of plug-ins can easily cost more than the mainframe.



Older digital frequency counters (such as the lower Hewlett-Packard 5245) can be relatively large with a maximum frequency range of about 50MHz but are built to an extremely high specification. The slightly newer Advance TC17 is of comparable size to modern gear

Provided size and weight are not a problem some very good oscilloscopes can be purchased for under £200. One example is the Cossor CDU 150, a portable 35MHz dual trace solid-state scope which features delayed sweep and quite a high specification for around £150-£200. The SE Labs SM111 is another portable solid-state oscilloscope with a bandwidth of 18MHz and the useful ability to operate from either mains or external DC supplies. Typical prices are around £120-£160.

The Tektronix 500 Series is a range of mainframe hybrid oscilloscopes which are physically large and weigh around 47kg. The 545A offers dual trace, dual timebase and delayed sweep with bandwidths up to 24MHz depending on the plug-in modules used and represents good value at around £70-£90. The slightly newer 547 offers all the same features with a bandwidth of up to 50MHz and can be thoroughly recommended at around £140-£160. The 585A again offers similar facilities and has a bandwidth of up to 85MHz but its small screen area makes it a poor choice unless the increased bandwidth is particularly important to you. It costs about the same as the 547.

Plug-in modules for the Tektronix 500 Series are widely available and range in price from around £10 up to £500-£600 or so for an IL20 Spectrum Analyser unit. Among the modules available are the Type M which provides 4-traces with a 20MHz bandwidth and the 1A1 which offers two traces at 50MHz bandwidth. Both cost around £60.

A wide range of Telequipment oscilloscopes is also available for under £200 and most represent very good value.

Signal Generators

These offer fewer advantages than oscilloscopes when bought second-hand, the vast majority of synthesised generators being very expensive even when they are no longer new. Standard (non-synthesised) signal generators have greater accuracy, a wider range of features and a better quality of construction when purchased second-hand but some are very large compared to their new rivals. Before buying it is advisable to check the following points:

- is it fully working in all modes and is the sine wave of adequate purity?
- is it accurately calibrated?
- does it have the modulation functions you require?

In the under £100 bracket there is a wide range of instruments — too many to cover fully here. However it should be possible to obtain fairly good but large AF and

RF generators for under £130. Examples include the Advance JI (AF) and the Marconi TF801D/8S (RF).

Voltmeters And Frequency Counters

The viability of secondhand units in these areas largely depends on their application. After all what's the advantage of having a 5½ digit second-hand voltmeter when you only require 3½ digit accuracy? You might as well buy a brand new 3½ digit voltmeter.

When buying a used digital voltmeter it is usually advisable to buy from a dealer which offers its own calibration service such as Electronic Brokers or Carston Electronics. Given the low price of DMMs a standard digital voltmeter can be a dubious buy, although the price of most of the older models reflects this: a Solartron A210 6 digit autoranging voltmeter can be bought for typically £30 from some dealers (uncalibrated).

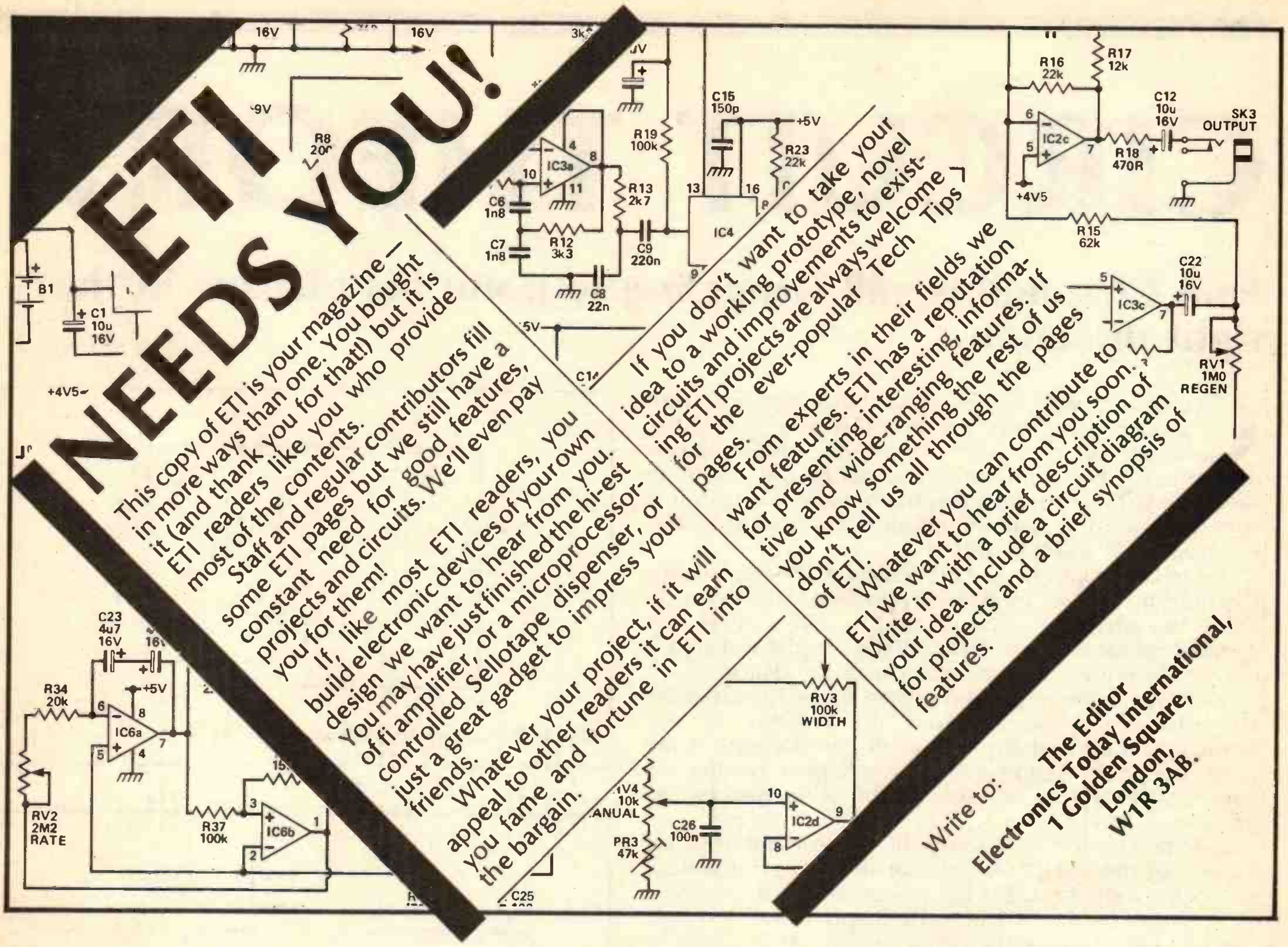
Special-purpose voltmeters such as those with true-RMS or high speed sampling facilities may represent better value for money when bought second-hand but even here the benefit is probably not great. The availability of advanced LSI and VLSI chips has brought us a wide range of new DVMs and DMMs with advanced specifications at comparatively low cost and when the difference in size and weight is taken into account the new instruments will almost invariably represent better value.

Frequency counters on the whole represent better value on the second user market than DVMs, but a careful evaluation of both the new and second-hand models available should be carried out before a decision is made. The older frequency counters can have restrictive bandwidths if they are to be used for RF work, although some such as the Hewlett Packard 5245L (with additional plug-in facility) and the advance TC17 also have timer functions which can be very useful for pulse duration measurement, etc. It is in this sector that the second-hand models are perhaps most cost effective.

The cheapest new counter timer (200MHz) costs around £175 while a second-hand unit with perhaps a bandwidth of 50MHz can be obtained for around £60. For around £200 a recent vintage counter should be available incorporating a fairly substantial number of functions. A number of advantages are to be had by purchasing second-hand frequency counters, such as oven controlled timebases and a more diverse range of functions but a new frequency-only model with perhaps eight times the bandwidth may often be bought for little more.

Conclusion

In most cases second-hand equipment represents a feasible alternative to new equipment in 'light use' or amateur stations but there are certain exceptions to this which have been pointed out. Second-hand test equipment can be purchased from several suppliers, some of whom advertise in this and other publications. A large price difference can sometimes be observed between the various dealers for apparently identical pieces of equipment but this usually reflects the condition of the instrument and the services offered by the dealer such as guarantees, etc. In spite of this it is still worth looking around and checking out the prices, especially in the older equipment. **ETI**



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CIRCUIT THEORY

Paul Chappell is still struggling to point his phasors in the right direction.

Continuing with the theme of phasor diagrams, we'll plunge straight in this month with a look at the circuit of Fig.1. Last month we drew phasor diagrams for two components in series but this time we've got parallel connections to consider too. Let's just continue with the same common sense approach and see how far it will take us.

From last month we can immediately draw our phasor diagrams for the two individual branches of the network. These are shown in Figs 2a and b. Not having any component values we don't know the lengths and angles but we do know the general form of the diagrams.

In Fig. 2a, for example, the voltage across the capacitor must lag the voltage across the resistor by 90° because the current through both components is the same. The phasor representing the voltage across the two components will be the sum of the other two voltage phasors.

Similar conditions hold for the resistor and inductor branch of the circuit except that this time the voltage across the inductor leads the voltage across the resistor.

To combine the two separate diagrams into a single diagram representing the whole circuit, we first have to determine the relationship between the phases of the two different branches. Following from last month I have used the current phasor as a reference for each branch and drawn it in the 'cosine' direction. If I immediately combine the two diagrams into one, I will be making the assumption that the currents in the two branches are in phase with each other, which is not necessarily the case.

One thing we do know is that the voltage across the resistor and capacitor must be exactly the same as the voltage across the resistor and inductor, so the phasors representing this voltage on the two diagrams must be one and the same. We can match up the V_{in} phasors by rotating one diagram or the other until they come into line.

Since V_{in} is the input voltage, it would be nice to have it pointing in the reference direction so that all the other voltages can be compared with it. This is done in Figs. 2c,d and the two diagrams are combined in Fig.2e.

We are still missing a phasor for the total current. This is just the sum of the currents in the two branches, so can easily be added. Note that the fact that it leads the input voltage in Fig.2e is just an accidental consequence of the way the original diagrams were drawn. When the diagram is scaled to suit real component values it could go either way. We don't know yet.

OK, let's put it to the test. In Fig.3 I've put in some values for the components. They are not very realistic values but don't worry. In a while I'll show you how to use totally ridiculous values (for *real* components) and *still* get the right answers!

Using Fig.2e as a model, we'll see if we can deduce enough information to draw up a complete phasor diagram for Fig.3. We'll begin with the easiest phasor of all and draw V_{in} in the cosine direction.

Now we're stuck. All the other phasors seem to involve knowing the value of i_1 or i_2 and we don't know either! Is there any way we can work them out? Looking back at Fig.2c for a moment, we know that the V_{in} phasor is

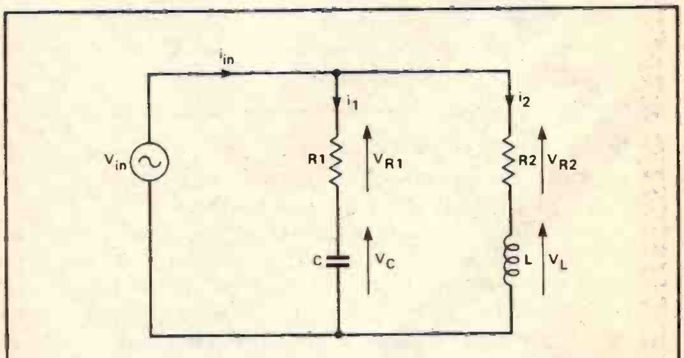


Fig. 1 The circuit to look at.

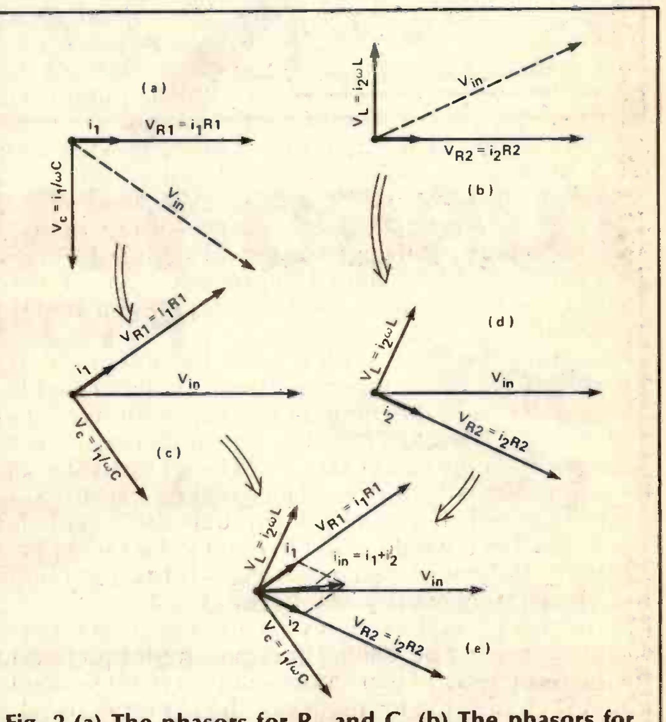


Fig. 2 (a) The phasors for R_1 and C. (b) The phasors for R_2 and L. (c) & (d) Rotating the phasor diagrams for the two halves to align the v_{in} phasor. (e) The complete phasor diagram.

the sum of the other two phasors and can be obtained by placing them nose to tail (Fig.4a). All we need to calculate the value of i_1 is to apply Pythagoras' theorem to the triangle (since the phasors for V_c and V_{R1} are at right angles).

$$5^2=(2i_1)^2+(\tfrac{i_1}{0.4}) = i_1{}^2(4+\tfrac{1}{0.16})$$

$$i_1{}^2=2.44$$

$$i_1=1.56$$

Now that we have the value of i_1 we can calculate $V_{R1}=2i_1=3.12V$ and $V_c=i_1/0.4=3.9V$. The angles can be

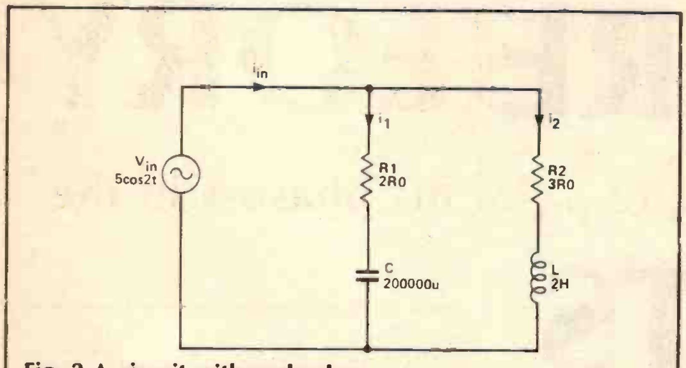


Fig. 3 A circuit with real values.

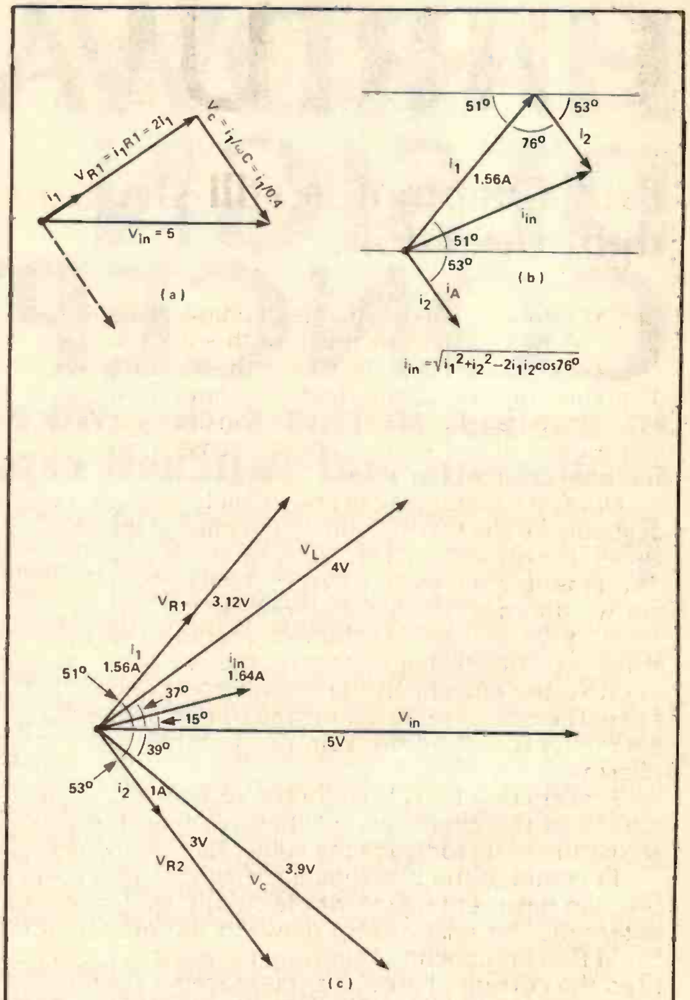


Fig. 4 (a) The phasors for R_1 and C. (b) The phasors for R_2 and L. (c) The complete phasor diagram.

obtained graphically by plotting the two phasors and using a protractor or simply by making use of the $\sin^{-1}$ and $\cos^{-1}$ buttons on your calculator!

A right-angled triangle based on Fig.2d will allow i_2, V_L and V_{R2} to be calculated in a similar manner. The current i_{in} is derived from the triangle formed by i_1 and i_2 as shown in Fig.4b. Since the triangle does not have a right angle, you'll have to use the 'cosine formula' to calculate the value of i_{in}. Don't worry if your trigonometry isn't up to the job — you can always draw the triangle and measure the side — or wait until next month when we do it the easy way!

The complete phasor diagram showing every single votage and current in the circuit is shown in Fig.4c. It shows that we can certainly find out how a circuit responds to a sine wave by using a little common sense and doing a few calculations but even for a circuit this size the simple idea of phasors is being spoiled by the amount of effort involved in working it all out.

What we really need is a procedure that will make things even clearer and can be used with complicated circuits where drawing phasor diagrams from first principles would be almost impossible. That's for next month. For the moment, we haven't quite finished with Fig.4c yet.

Suppose we had started with the circuit of Fig.5 instead of Fig.3. The input frequency is increased by a factor of 1000 and the inductor and capacitor have values reduced by a factor of 1000. The impedance of the inductor will now be 2x1000 x 2÷1000=4. Exactly the same as before! Similarly the impedance of the capacitor would be unchanged. If you check through the calculations you'll see that it would result in exactly the same phasor diagram. The only thing that changes is that the phasors are all spinning round 1000 times as fast.

This result applies to any circuit and to any scaling factor (it needn't be 1000). Note that the frequency *and* all the inductor and capacitors values must be scaled. If you just change the frequency or the component values individually, the response of the circuit will be entirely different. Component values around one Henry and one Farad are easiest for calculation and the notion of frequency scaling allows one circuit to speak for a whole class of circuits.

For published data the usual choice is to make ω=1, giving 'normalised' component values. To calculate the component values needed for a real circuit, all you do is to divide the published values by the angular frequency you want the circuit to work at!

Have a look at the relationship of the currents in Fig.1 to the input voltage. The currents in the two individual branches of the network are considerably different in phase from the input voltage but the overall current is only 15° out of phase so the network as a whole looks 'almost' resistive. Is it possible to choose component values to make it appear exactly resistive to the input? If we imagine that R_2 is the resistance of a loudspeaker

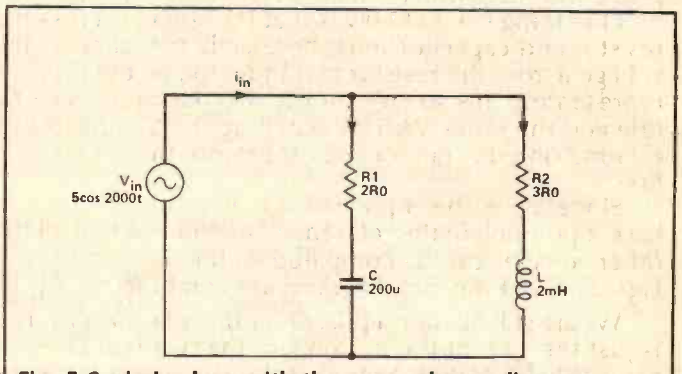


Fig. 5 Scaled values with the same phasor diagram.

coil and L is its inductance, then to a first approximation we have just drawn the phasor diagram for an amplifier driving a loudspeaker and Zobel network. The component values are not quite right but the principle is just the same. The question of just how resistive we can make the load look to the amplifier is quite important.

With circuits working at rather higher frequencies a similar question arises: how can unwanted circuit elements be 'tuned out' or 'neutralised'? If it can be done at all, will it work for all frequencies? If not, how close can we get to a pure resistance over the frequency range of interest? Our common sense approach doesn't seem to be making the answers very clear, so next month we'll start to refine it a little.

ETI

HARDWARE DESIGN CONCEPTS

In the last in this series Mike Barwise looks at the integrated continuous and switched capacitor filters.

Filters figure prominently in analogue signal processing. Their uses range from the simple elimination of spurious signals (such as the removal of mains hum in audio amplifiers) to the separation of complex signals into their basic components in instruments like spectrum analysers.

The two fundamental types of filters are *passive* and *active*. Passive filters use series/parallel networks of inductances and capacitors, taking advantage of the reciprocal impedance characteristics of these devices with frequency. The problem with the simplest passive filters is the poor 'rolloff' characteristic — the graph of attenuation versus frequency (Fig.1). In order to improve this characteristic, additional elements are added to the network (Fig.2) but the calculation of component values gets increasingly tricky as more 'poles' (series or parallel elements) are added.

The classical solution to this problem is the use of *active* filters. These again use the impedance versus frequency (Z:f) characteristics of capacitors and inductors (or more often, resistors) as the control but in this case they are included in the feedback loop of an operational amplifier (Fig.3).

Such filters are very adaptable, capable of very high orders of rolloff and horribly difficult to design. Another point worthy of mention is the filter 'passband characteristic'. Our simplest passive filter had a rolloff but no flat passband, in that there was a continuous relationship between attenuation and frequency (3dB per octave) throughout its working range.

Once you have a sharp cutoff characteristic (Fig.4) it becomes important how flat the response is in the passband. Various different tradeoffs between cutoff and passband flatness have been adopted as classic models:

BUTTERWORTH maximal flatness in passband, moderate rolloff

CHEBYSHEV maximal rolloff, ripple in passband

To design an active filter with a sharp cutoff at a predictable frequency together with a desired passband flatness characteristic, the maths is quite horrific. The good news is that there is a short cut.

Several semiconductor manufacturers have produced ready made filter building blocks which greatly simplify the design of good filters. A couple of these devices have additional advantages which allow otherwise ferocious problems to be solved quite easily as well, so let's look at a selection.

Integrated Filter Types

There are two device series that I shall discuss, working on different principles. The first is a range of fairly conventional op-amp/R/C filters by Datel. These are 'continuous' signal filters which work on the same

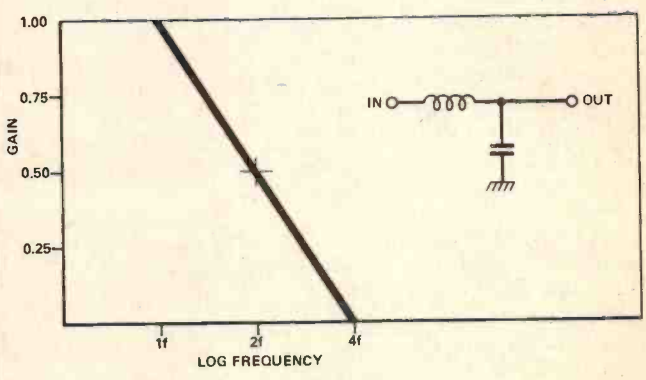


Fig. 1 Rolloff with a simple two pole filter.

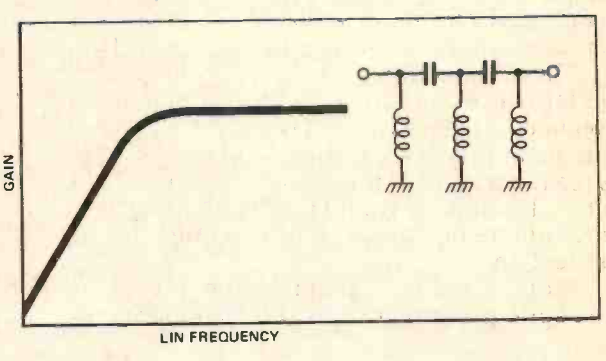


Fig. 2 Better rolloff with a five pole filter.

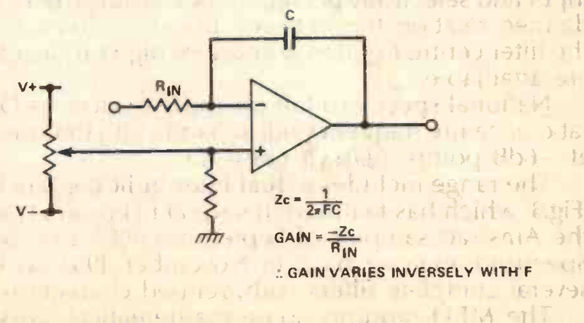


Fig. 3 An active filter with offset adjustment.

principle as the discrete component active filter.

The second type is a range of 'switched capacitor' filters by National Semiconductor. These work on an entirely different principle. They sample the incoming signal at a predetermined rate and pass on to the output only the wanted components. This means that if you look at the filter output waveform on a scope you will see that it consists of many small steps instead of a continuous curve. Occasionally this may cause problems but usually it can be tolerated as a tradeoff against some very powerful advantages which result from this approach.

Datel Tuneable Filters

The Datel range is built around a basic hybrid filter series designated FLJ-UR (Fig.5). These are small single-in-line packages containing various alternative filters. High, low and bandpass are all available in Butterworth characteristic and low and highpass are also available in Chebyshev. There are two frequency bands available: HF 400Hz–5/10/20KHz, and LF 40Hz–1.6KHz. The required frequency (Fc) is set by the addition of up to four external resistors — the only external components for normal use. The response of the LF filters may be extended downwards by the addition of suitable capacitors, when it should be possible to achieve Fc as low as 0.1Hz at the expense of slightly increased noise. The FLJ-UR filters have a fixed rolloff of typically 24dB/octave.

A really crafty addition is the FLJ-ACR1, 2 range of *Logic controlled resistor networks* (Fig.6). These are quite costly, but allow BCD digital control of the filter Fc to within 1% when used with the FLJ-UR filters. Each resistor network contributes one BCD digit of control but they can be cascaded for more resolution.

A spinoff from these basic components is the Datel FLJ-D series of universal programmable filters (Fig.7). These are over-width DIL hybrids containing all components barring a couple of resistors and capacitors which define the gain and rolloff the filter. Low, high and bandpass outputs are available simultaneously from the package and Fc is set by a three-digit BCD input word.

These Datel filters have very good general analogue performance and can be highly recommended anywhere you need a range-switched or fixed-frequency filter. Their one main drawback is their limited Fc *settability* which is really a feature of the resistor networks rather than the filters. If someone would produce a quad gang precision potentiometer, these filters would be useable to perfection.

More settable, though by no means so good in analogue performance, is the National range.

National Switched Capacitor Filters

The National MF series of filters and filter building blocks are 'switched capacitor' or 'sampling' filters. The incoming waveform is sampled at a rate set by a clock input and selectively passed to the output. There is a well defined relationship between the clock frequency and the filter centre frequency and very high orders of rolloff are attainable.

National specify rolloff for these devices as Q — the ratio of centre frequency (f0) to bandwidth (bw) measured at −6dB points: (f0/bw(−6dB))=Q.

The range includes a dual filter building block MF10 (Fig.8) which has featured in several ETI projects such as the Amstrad sampler of September 1987 and even the Spectrum analyser back in November 1982, as well as several complete filters with defined characteristics.

The MF10 requires some mathematical working to derive an external resistor network. It is, however a very flexible device, allowing low, high, band, notch and all-pass filters of defined Q to be created by variations in the R network.

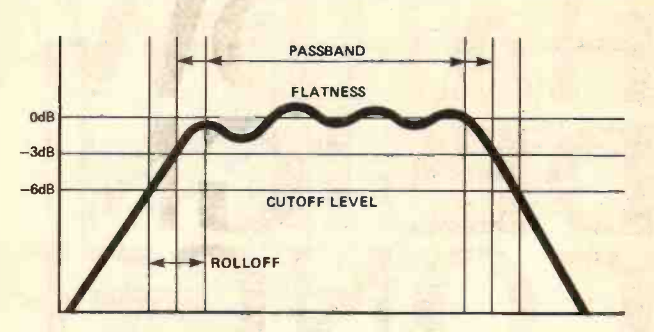


Fig. 4 Passband flatness of a (bad) high order bandpass filter.

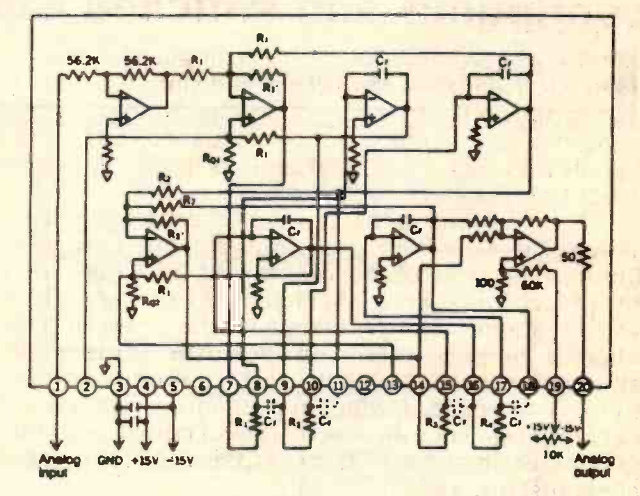


Fig. 5 The FLJ-UR hybrid filter.

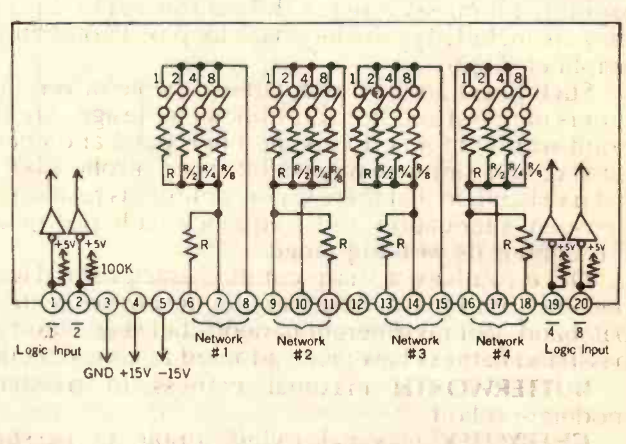


Fig. 6 FLJ-ACR1 logic controlled resistor network.

Of the complete filters, worthy of mention are the MF4 Butterworth low-pass and the most interesting of all, the new MF8 fourth order bandpass filter.

The MF8 (Fig.9) contains two identical bandpass filters which may be cascaded. They are both driven by a common clock and their Q is adjustable by a common 5-bit digital input word. The nominal centre frequency is settable to either clock/50 or clock/100 within a centre frequency range of 0.1Hz to 20KHz (at clock 50) with a maximum clock of 1MHz. The actual f0 deviates slightly from this nominal according to the Q setting (about 10% worst case) but this is well documented and should pose no problems.

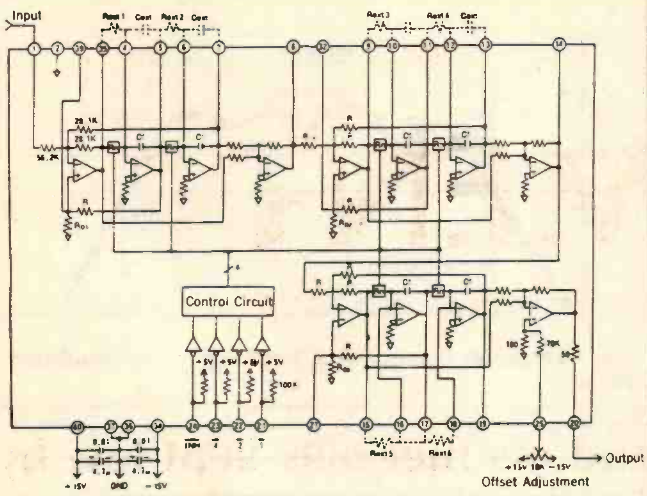


Fig. 7 FLJ-D universal programmable filter.

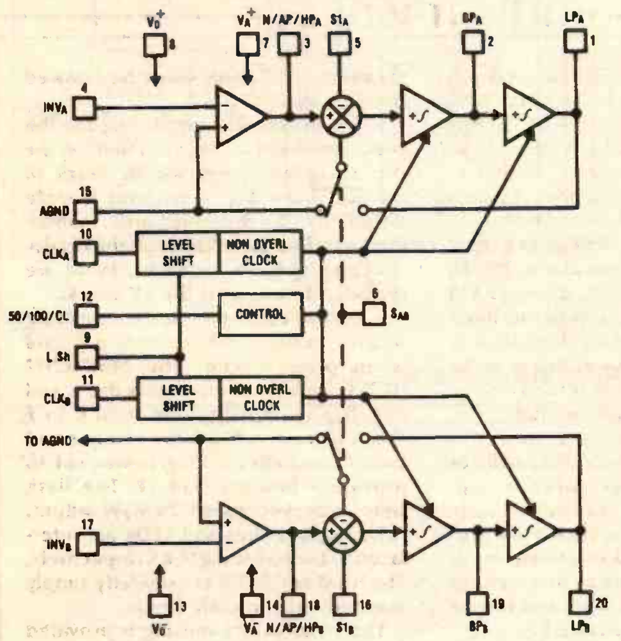


Fig. 8 The MF10 switched capacitor filter.

In conventional fixed frequency applications, well defined passband characteristics can be attained by the use of external feedback resistors in conjunction with an uncommitted op-amp also included in the chip (Fig.10). However, where a less defined passband characteristic can be tolerated, particularly where a very narrow passband is required, the MF8 can be used with no external components to create a single chip bandpass filter capable of variable Q in the range of at least 0.5 (very slow rolloff) to 90 (too much for almost anyone!).

Note that in this configuration there is no *flat passband*. The Q programming simply defines the gradient of the rolloff about f0. Add to the Q control the direct control of the centre frequency by external adjustment of clock rate and you have a very valuable *tracking bandpass filter* which is entirely digitally controlled.

This highly controllable filter is a valuable data logger front end, where it can perform many jobs from programmable anti-aliasing to simple spectrum analysis of continuous waveforms or, for example, be used at high Q to indicate transient presence of a specified frequency component in a complex waveform.

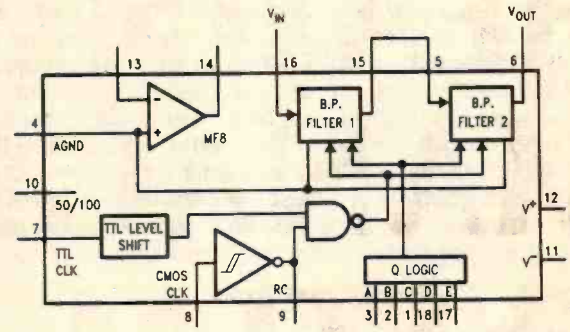


Fig. 9 The MF8 switched capacitor filter.

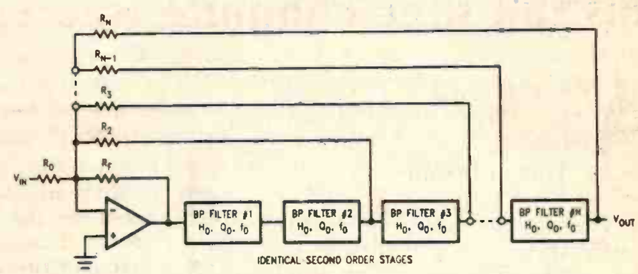


Fig. 10 Using the uncommited op-amp of the MF8 for well defined passband characteristics.

Being a sampling device, the question of 'aliasing' is sure to be raised in relation to the MF filter itself. The basis of aliasing is the concept that it is impossible to recover by sampling techniques a waveform whose period is equal to or greater than half the sampling rate. Under these conditions, a bogus frequency component is observed with a frequency greater than half the sampling rate by the same amount as the real component is below it. This looks similar to the upper and lower 'sidebands' in radio communications.

In the MF filter range, the maximal bandwidth of the analogue channel is much less than half the clock (sampling) rate under most conditions, so aliasing should not be a problem. In fact the MF10 could form the basis of an ideal digitiser anti-aliasing filter, in low-pass configuration with the f0 clock driven by the same clock as the ADC conversion trigger.

The final point of caution with these switched capacitor filters is their analogue performance (drift over temperature, absolute device variation and so on). They are potentially not so precise as a continuous filter and they can be quite noisy. There is inevitable clock breakthrough, although this is usually outside the band of interest and their analogue channel noise is likely to be worse than, for example, the Datel continuous filters.

Really, you have to make a choice between the trade-offs. For a fixed filter, I would go for the Datel range every time (subject to cost) but where automatic tracking capability is required, any alternative to the switched capacitor filter with clock control is a really tricky design problem.

I hope these comments have got your fingers itching to get their grip on these devices. Further information on the Datel range can be obtained from Datel (UK). Tel: (0256) 469085. Prices range from the £24 mark. The National MF series are available from many distributors, and the MF8 should be joining the others shortly at a list price around £5 or so.

ETI

HEATING MANAGEMENT SYSTEM

Harry Bloomfield is kept warm and his fuel bills kept low by this full spec computerised central heating controller.

A central heating system is nowadays considered an essential for any large flat or house. This controller replaces the usual standard, electro-mechanical clocks and thermostats with a single, versatile and reliable microprocessor based control. This controller is not only an advance over the electro-mechanical systems but also over most commercial electronic add-on controllers.

The main features of the Heating Management System are:

- many fold increase in system reliability
- complex and versatile control programs can be used without reliability suffering
- control of temperature and timing is to a far greater accuracy for greater comfort and economy

The management system offers independent control of two central heating zones — usually upstairs and downstairs — and the water heating.

The temperature of the zones and water can be programmed to vary as the day progresses as well as providing the more normal on/off functions.

Options

With some heating systems it may not be practical to split the home into two heating zones. In this case one relay along with its associated suppression components and temperature sensor can be omitted.

The PCB is designed for a 2732 EPROM (IC5). As the software occupies just 2K a 2716 can be fitted if the track to pin 21 is cut and the pin connected to +5V with an insulated wire link.

The PCB is also designed for a 6116 battery backable RAM chip. Battery backing of the RAM is only necessary if optimising software is to be used (see below) and so a cheaper 4116 RAM can be used instead if the track to pin 24 is cut and the pin connected to the 5V rail.

Four sensors are provided for. The external sensor is optional

HOW IT WORKS

The heart of the controller circuit (Fig.1) is the microprocessor. In this case I have used the old faithful 8085 (IC1). This derives its clock signal from the versatile but underused HD146818P real time clock chip (IC2). This provides registers for seconds, minutes, hours, day, month, and year and provides 50 bytes of battery backed RAM and various alarm signals.

Only the minutes, hours, day and RAM are used in this application. The three alarm registers are set up then used as check bytes after a power cut to make sure the clock still contains valid data — that the battery has not run flat.

The clock chip also provides a 1.048576MHz clock (the crystal oscillator clock divided by four) whic is supplied to the processor and divided again by two to 0.524288MHz. Such a low processing speed is used to ensure maximum immunity to noise, to create as little as possible noise itself and to give the unit a long and reliable life.

R1,2, C1,2, D6,7 and Q1 form a mains failure detection circuit. The instant the mains supply is lost the base of Q1 goes low and this in turn pulls the processor Reset line low. This stops the processor and switches the clock chip RAM (IC2) to battery backup.

Data corruption of the RAM on switch over to battery power is a common problem with this type of chip. However, this simple mains failure circuit worked perfectly without data corruption with 10,000 artificial mains failures during testing.

The 5V regulator (IC15) has a forward biased diode on its ground terminal to raise the output voltage to about 5.6V. This enables the main supply rail to be separated from the battery rail by diodes D8,9 to provide a charging current for the battery (B1) through R28. However, this means the regulator must be isolated from its heatsink.

IC3 provides demultiplexing for the processor address bus. Each item on the bus occupies a separate 8K block of memory (see Fig.2) enabling simple decoding of the three high order address lines only by IC4. So although the display occupies only six locations, these are repeated throughout the 8K block.

IC7 provides the time and temperature display during both normal use and when programming. The MM74C917 (IC7) is capable of driving six digits and can display any character from 0 to F (hex). It can also blank the displays and this is used after a long power cut to provide a flashing FFFF FF. The flash signal is derived from IC2's SQW output.

The keyswitches and LEDs are interfaced to the bus using IC8,9 respectively. The RAM and ROM are similarly simply mapped each into 8K blocks.

The temperature sensing is provided by four LM335Z chips (IC16-19). At −27.5°C the output from these is 2.4565V and at 100°C output is 3.7315V (10mV/°C). This works out at 0.5°C per binary step from the ADC chip (IC11) — 256 steps from −27.5 to 100°C.

An accurate and temperature stable reference for the ADC chip is provided by Q8 operating as a constant current source supplying the precision voltage reference, IC20. This is divided by resistor chain R11, RV1, RV12, RV2 and buffered by IC12 to provide the upper and lower reference voltages at IC11.

R29 and C6 decouple IC11 and R7-10, C7-10 provide crude input filtering. Additional smoothing is provided by the software. An average value for each of the four channels is obtained from 256 separate ADC readings.

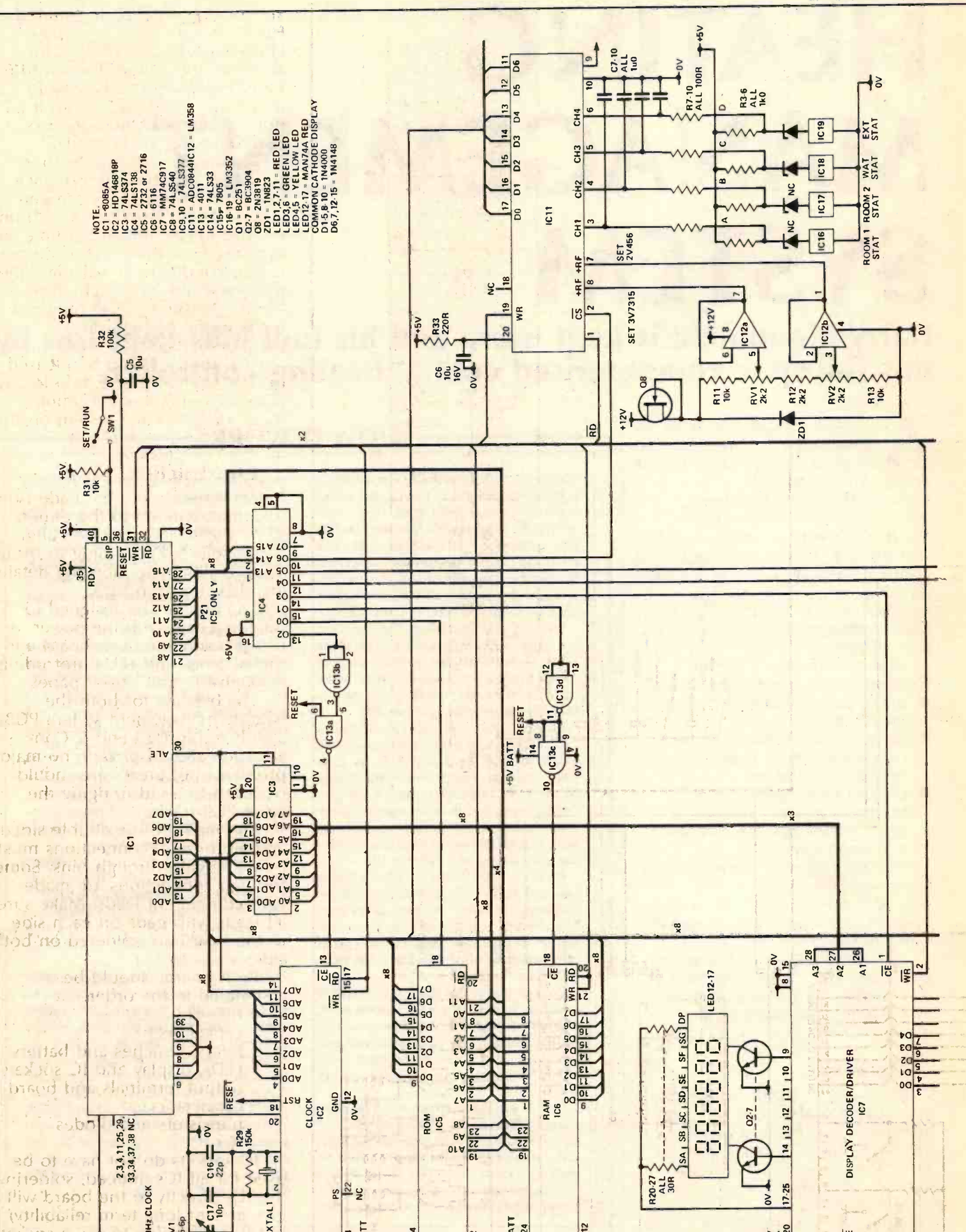
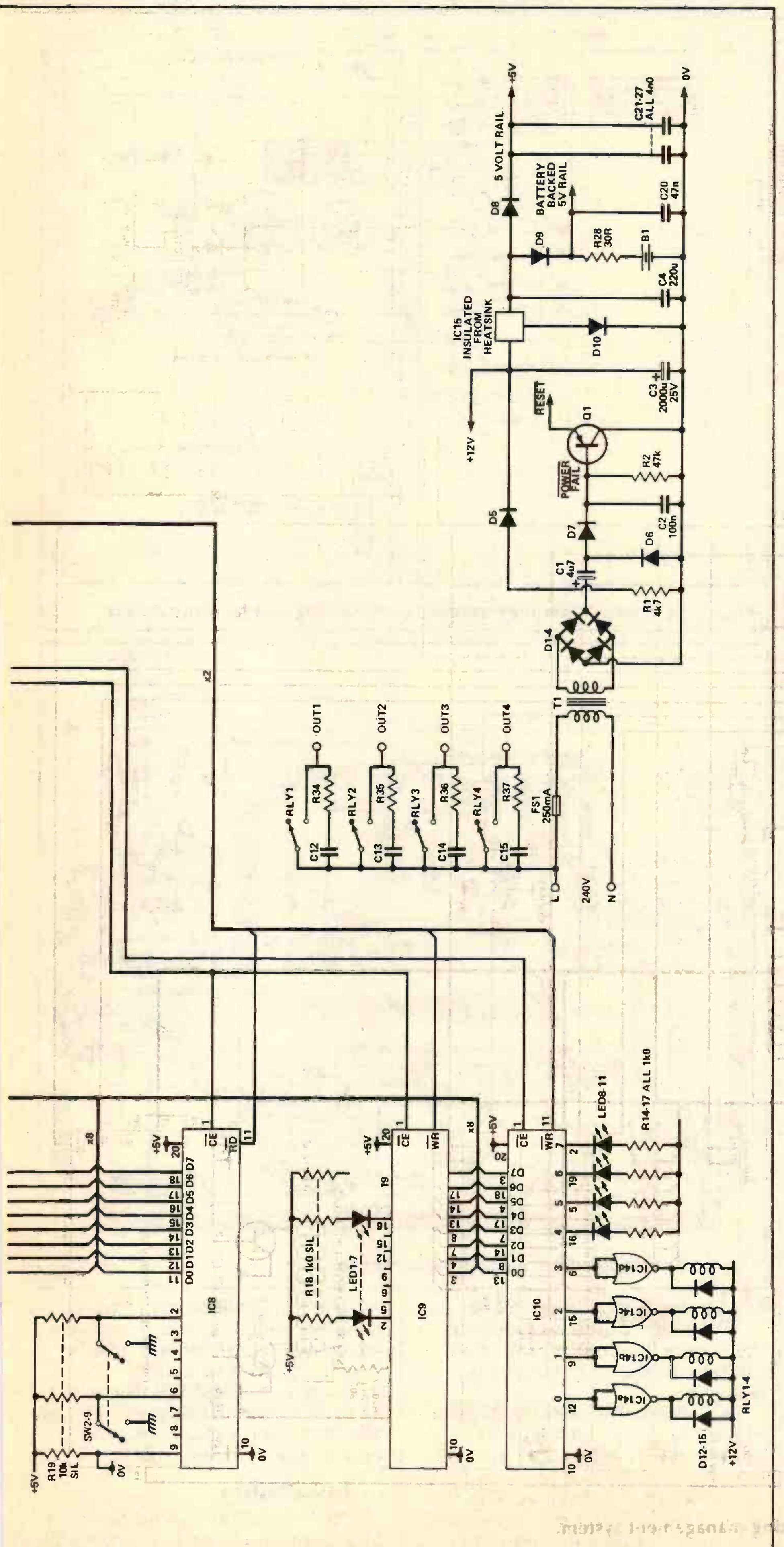


Fig.1 The circuit diagram of the heating management system.



and can be installed if required. However, with the larger size EPROM to contain some extra software, the battery backed 6116 RAM and the external sensor mounted out of the sun on a north facing wall, an optimised controller may be created.

This would make a decision based on previous performance and inside and outside temperatures. Rather than just switch on the heating at the alotted time, an optimised controller uses the prevailing conditions to calculate the time required for switch-on to bring the house to the required temperature by the time programmed.

The author would be pleased to hear from and give help to any reader wishing to try to implement an optimising system on this controller.

Construction

The case should be made from folded aluminium to the dimensions shown in Fig.3 or an alternative selected according to these sizes. Drilling and labelling details are also shown in Fig.3.

The boards are designed to plug together, with the power board below the main board and the switches and LEDs protruding through the unit's front panel.

The overlays for both the heating management system PCBs are shown in Fig.4 and 5. Construction should provide no major problems but great care should be taken to avoid bridging the close PCB tracks.

The main PCB is double sided and all through connections must be made with through pins. Some through connections are made with component leads. Make sure all leads with pads on each side of the board are soldered on both sides.

Both boards should be assembled in the order:

- resistors
- capacitors
- relays, switches and battery
- LEDs, display and IC sockets
- output terminals and board connectors
- transistors and diodes
- ICs

IC sockets do not have to be used for all ICs (indeed, soldering the ICs directly to the board will give greater long term reliability) but it is advisable to use a socket for the EPROM (IC5).

When both boards are completed and checked to be operational they should be coated with a suitable protective laquer

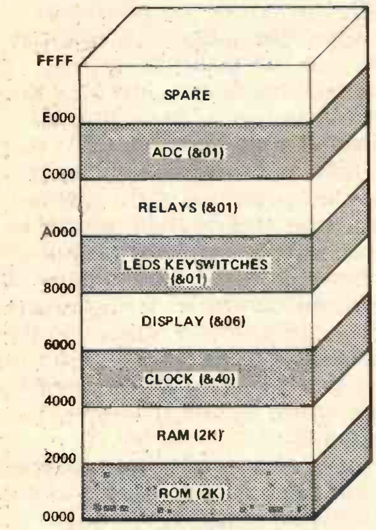


Fig.2 The memory map of the system. The figures in brackets give the number of locations actually used by each peripheral in the map, repeated through the 8K blocks.

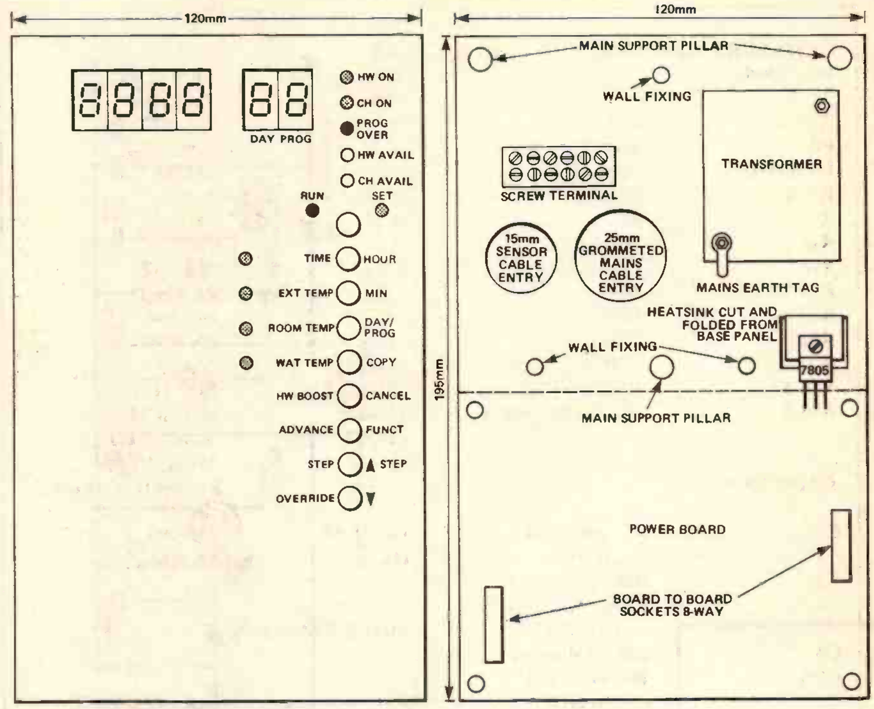


Fig.3 Case construction measurements and drilling and labelling details.

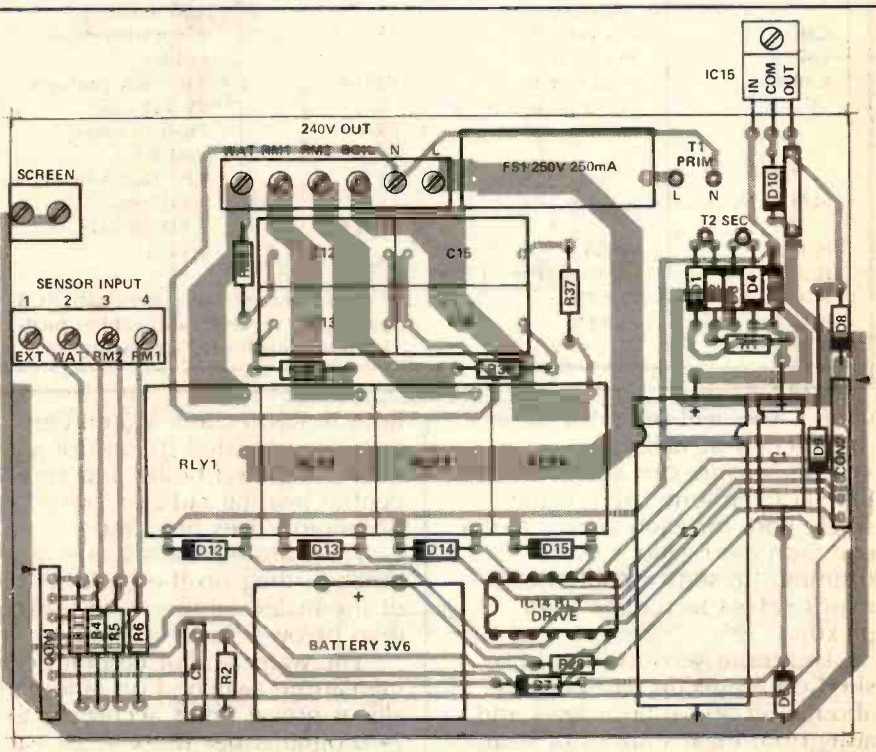


Fig.4 The component overlay of the power board.

to prevent moisture attacking the tracks and to add extra insulation around the main tracks.

The EPROM (IC5) should be programmed with the software given in Listing 1. Ready programmed EPROMs are available from the author (see Buylines).

Testing And Calibration

Connect a temporary mains supply to the power board alone. The relays should click in and the 5V supply rail, 5V battery rail and the 12V relay rail should be checked with a multimeter. Switch off.

Connect two temperature sensors between the *Rm1* input and the screen terminals and between the *Wat* input and *screen*. The probes themselves should be well insulated and waterproofed with heat shrink sleaving or epoxy resin.

Connect the main board to the power board, switch on again and the display should show a flashing FFFF FF. This confirms that most of the circuitry is working.

Press SET/RUN then HOUR. The display should show 00.00 1d. Press SET/RUN (the display should show 00.00 10) and then ROOM TEMP. The display will now display the temperature of the *Rm1* probe.

Place this in iced water and adjust RV2 so the display shows 00.00.

Now press the WATER TEMP button and with the second probe in boiling distilled water adjust RV1 so the display reads 99.50.

RV1 and RV2 interact and so the process should be repeated until no further adjustment is required.

An alternative method of calibration is to use an accurate multimeter to adjust RV1 for a reading of 3.7315V at pin 7 of IC12. Adjust RV2 for 2.4565V at IC12 pin 1. This is much quicker (and less messy!) but does require an accurate meter.

The final calibration required is of the system clock. If an accurate frequency meter is available adjust VC1 to give a clock frequency of 1.0485760MHz at pin 21 of IC2. Alternatively VC1 can be adjusted over a few weeks to correct the real time clock.

Installation

The controller should be fixed in a position in the house suitable for both convenient use and tidy

PARTS LIST

RESISTORS (all ⅛W, 5% unless specified)

R1	4k7
R2	47k
R3-6,14-17	1k0
R7-10	100R
R11,13,31	10k
R18	1k0 x 8 SIL
R19	10k x 8 SIL
R20-28,38,39	30R
R29	150k
R32	100k
R33	220R
R34-37	100R ¼W
RV1,2	2k2 horiz preset

CAPACITORS

C1	4µ7 16V axial electrolytic
C2	100n polyester
C3	2000µ 25V axial electrolytic
C4	220µ polyester
C5,6	10µ 16V axial electrolytic
C7-10	10µ 16V tantalum
C12-15	100n 250VAC suppression
C16	22p ceramic
C17	10p ceramic
C20-27	47n ceramic
VC1	1.5-6p miniature preset

SEMICONDUCTORS

IC1	8085A
IC2	HD146818P
IC3	74LS374
IC4	74LS138
IC5	2732 or 2716
IC6	6116
IC7	MM74C917
IC8	74LS540
IC9,10	74LS377
IC11	ADC0844
IC12	LM358
IC13	4011
IC14	74LS33
IC15	7805
IC16-19	LM335Z
Q1	BC251
Q2-7	BC3904
Q8	2N3819
ZD1	1N823
LED1,2,7-11	Red LED
LED3,6	Green LED
LED4,5	Yellow LED
LED12-17	MAN74A red common cathode display
D1-5,8-10	1N4000
D6,7,12-15	1N4148

MISCELLANEOUS

B1	3v6 100mA NiCd
CON1,2	8 way PCB connectors, male and female
FS1	250mA fuse and holder
RLY1-4	250V 10A contacts 5V TTL coil
SW1-9	Push to make switch
T1	12V 750mA mains transformer
XTAL1	4.194304MHz crystal

PCB; PCB-mount mains terminals; PCB spacers; IC sockets; case; cables; heat-sink mounting for IC15; nuts and bolts.

wiring. This will probably be in the kitchen or hall.

The sensors can all be connected via telephone cable using a single core for each sensor and a common connection. Avoid running the sensor cable near mains cables to reduce hum pickup.

The room sensors should be sited on an inside partition wall about 5-6ft above floor level and away from local sources of heat. The water sensor should be taped directly onto the copper of the hot water cylinder, about halfway up.

The mains wiring should all be in suitable cable and powered from a 5A fused supply. Special care should be taken to ensure adequate earthing.

Specification And Operation

Four temperature sensing inputs are provided — External, Room1, Room2 and Water. Outputs are provided to control a mains activated boiler and two central heating radiator zones (solenoid valves or pumps).

Frost protection is active at all times turning on the boiler if any of the inside temperature sensors read below 5°C.

The water and/or central heating can be switched on automatically at preset times according to 24 programs per week — six each for Saturday, Sunday and all the weekdays plus another six for a 'floating' day to replace any weekday (for, say, a shop's early closing day).

Each program allows the central heating or hot water to be switched on, or both on or both off. Program overrides allow for a tankful of water (say, for a bath), a temporary override until the next program and a semi-permanent override for summer or during a holiday (frost protection is still maintained).

Both hot water and central heating automatically turn off at midnight unless the next day's program turns them on again at that time.

Hot water and central heating temperatures can also be controlled. The weekend and weekdays are divided into six periods and the temperature for the hot water and central heating can be set separately for each period.

Program times and temperatures are retained during power failure for over 100 hours.

The LED display gives the time and instantaneous readings of temperature from all sensors in the range −27.5°C to 99.5°C.

The controls can be password locked against tampering.

Start Up

On switch-on the frost protection is in operation and (after setting the time — see below) the following preset programs are operative:

Sunday	(1)	Weekdays	(d)
07.30	HW & CH	06.30	HW & CH
09.30	CH	09.00	
12.00	HW & CH	12.00	HW & CH
14.00	CH	13.30	
17.00	HW & CH	16.30	HW & CH
19.00	CH	19.30	CH

Saturday	(7)	Float day (set to Friday)	(F)
07.00	HW & CH	06.30	HW & CH
09.30	CH	09.00	
12.00	HW & CH	12.00	HW & CH
14.00	CH	13.30	
17.00	HW & CH	15.00	HW & CH
19.00	CH	19.30	CH

Time	CH	HW
Weekends		
00.00-08.00	12°	45°
08.00-10.00	21°	60°
10.00-12.40	18°	50°
12.40-14.00	20°	60°
14.00-17.00	19°	50°
17.00-00.00	22°	60°
Weekdays		
00.00-06.30	12°	45°
06.30-09.00	21°	60°
09.00-11.00	17°	50°
11.00-13.00	20°	60°
13.00-17.00	15°	50°
17.00-00.00	21°	60°

Pressing the SET/RUN button will put the controller into Set or Run mode as indicated by the red and green LEDs on the front panel.

0000	31	FF	27	AF	CD	0B	03	CD	2E	03	21	00	20	0E	FF	36
0010	00	23	0D	C2	0F	00	3E	FF	CD	DE	05	21	00	20	CD	E1
0020	05	21	01	40	CD	27	01	3E	22	B8	C2	68	07	3E	35	B9
0030	C2	68	07	3E	16	BA	C2	68	07	3A	3F	40	FE	8B	C2	68
0040	07	CD	24	01	32	07	20	CD	42	01	CD	59	01	21	10	20
0050	34	3A	0A	20	E6	F0	FE	80	C2	62	00	3A	02	20	CD	6F
0060	02	AF	FE	40	C2	6E	00	3A	00	20	CD	6F	02	AF	FE	20
0070	C2	7A	00	3A	03	20	CD	6F	02	AF	FE	10	C2	82	00	CD
0080	CF	01	CD	E0	01	7D	D6	27	32	13	20	CD	36	02	A3	47
0090	3A	17	20	BB	CA	A3	00	7B	32	17	20	3A	0F	20	E6	80
00A0	32	0F	20	7B	CD	AF	02	CD	DC	02	3A	0C	20	6F	3A	26
00B0	40	E6	0F	A5	6F	3A	0F	20	E6	08	7D	CA	C7	00	3A	0F
00C0	20	E6	03	6F	5F	F6	80	07	07	07	67	3A	0F	20	E6	80
00D0	07	B5	6F	3A	09	20	A5	B4	6F	3A	12	20	2F	E6	20	B5
00E0	CD	FC	02	7D	E6	03	6F	7A	E6	02	07	B5	6F	3A	09	20
00F0	A5	CD	A9	07	E6	F0	B5	6F	3A	08	20	B5	CD	0B	03	06
0100	10	0E	FF	3A	12	20	FE	FF	CA	11	01	CD	15	03	CA	E7
0110	03	3A	00	80	FE	00	C2	38	03	0D	C2	03	01	05	C2	01
0120	01	C3	41	00	21	02	40	3A	0A	40	E6	80	C2	27	01	46
0130	23	23	4E	23	23	56	21	04	20	70	23	71	23	72	CD	32
0140	07	C9	21	00	20	1E	04	E5	CD	4C	07	E1	7E	B0	1F	77
0150	2C	1C	7B	FE	08	C8	C3	47	01	21	9E	07	11	2D	40	3A
0160	06	20	FE	01	CA	6C	01	FE	07	C2	72	01	21	98	07	11
0170	27	40	23	13	4E	3A	07	20	B9	D2	72	01	1B	EB	7E	CD
0180	F2	06	32	0E	20	11	0C	00	19	7E	CD	F9	06	32	0D	20
0190	0E	00	1E	02	21	FF	1F	CD	B9	01	1E	04	CD	B9	01	1E
01A0	01	3A	0D	20	32	0E	20	CD	B9	01	79	32	09	20	0F	D8
01B0	3A	0F	20	E6	0F	32	0F	20	C9	23	46	3A	0A	20	A3	3A
01C0	0E	20	CA	C7	01	C6	04	D6	02	B8	D8	79	B3	4F	C9	2E
01D0	01	3A	05	20	CD	9B	02	2E	03	3A	04	20	CD	9B	02	C9
01E0	0E	06	1E	F0	26	40	3A	06	20	FE	01	C2	F3	01	2E	0E
01F0	C3	15	02	FE	07	C2	FD	01	2E	1A	C3	15	02	47	3A	26
0200	40	0F	0F	0F	0F	E6	0F	B8	C2	0E	02	2E	20	AF	FE	00
0210	CA	15	02	2E	14	3A	07	20	BE	DA	21	02	23	0D	C2	15
0220	02	79	FE	06	CA	2A	02	1E	FF	2B	7D	C6	19	6F	7E	A3
0230	E6	03	32	0C	20	C9	3A	13	20	06	00	FE	05	CA	49	02
0240	DA	49	02	04	D6	06	C3	3B	02	4F	0C	78	FE	03	C2	56
0250	02	3A	26	40	E6	F0	FE	02	C2	5D	02	3E	70	FE	01	C2
0260	64	02	3E	D0	FE	00	C2	6B	02	3E	10	B1	2E	05	C9	FE
0270	3F	D2	80	02	47	3E	10	32	11	20	3E	37	90	C3	82	02
0280	D6	37	1F	47	DA	8E	02	AF	32	02	60	C3	93	02	3E	05
0290	32	02	60	3E	0C	32	03	60	2E	01	78	06	00	FE	0A	DA
02A0	A8	02	04	D6	0A	C3	9D	02	4F	78	0F	0F	0F	0F	B1	47
02B0	E6	0F	4F	7D	26	60	FE	01	79	C2	C7	02	5F	3A	10	20
02C0	E6	01	0F	0F	0F	0F	B3	77	2B	78	1F	1F	1F	1F	E6	0F
02D0	5F	3A	11	20	B3	77	AF	32	11	20	7B	C9	21	FF	1F	3E
02E0	43	32	0E	20	0E	00	1E	07	16	03	CD	B9	01	15	C2	EA
02F0	02	79	A3	CA	F8	02	3E	0F	32	0B	20	C9	32	0B	20	2F
0300	32	00	80	AF	C9	3A	0A	20	E6	0F	B0	32	0A	20	EE	F0
0310	32	00	A0	AF	C9	20	E6	80	C0	20	E6	80	CA	19	03	AF
0320	C9	06	3F	0E	FF	0D	C2	25	03	05	C2	23	03	C9	16	06
0330	CD	21	03	15	C2	30	03	C9	3A	00	80	FE	80	C2	45	03
0340	06	10	CD	05	03	FE	40	C2	4F	03	06	20	CD	05	03	FE
0350	20	C2	59	03	06	40	CD	05	03	FE	10	C2	63	03	06	80
0360	CD	05	03	47	3A	AB	07	B8	C2	7D	03	CD	2E	03	3A	00
0370	80	47	3A	AB	07	B8	C2	7D	03	AF	32	12	20	3A	12	20
0380	FE	00	C2	FF	00	3A	00	80	FE	01	C2	93	03	21	26	40
0390	CD	B8	03	FE	04	C2	9E	03	21	0F	20	CD	B8	03	FE	08
03A0	C2	AB	03	3A	0F	20	F6	80	32	0F	20	FE	81	C2	FF	00
03B0	3E	FF	32	12	20	C3	FF	00	7E	E6	03	5F	07	07	07	57
03C0	3A	0B	20	E6	E7	B2	CD	FC	02	CD	21	03	3A	00	80	E6
03D0	02	C2	D8	03	E1	C3	B5	03	1C	7B	E6	03	4F	7E	E6	FC
03E0	B1	F6	08	77	C3	B8	03	3E	40	CD	FC	02	3E	01	32	10
03F0	20	AF	32	16	20	3E	10	CD	0B	03	CD	15	03	CA	40	04
0400	3A	00	80	4F	FE	04	C2	23	04	3A	0A	20	FE	80	C2	13
0410	04	3E	08	07	47	CD	05	03	32	13	20	3E	40	CD	FC	02
0420	CD	BF	05	3A	0A	20	FE	10	CC	4B	04	FE	20	CC	D6	04
0430	FE	40	CC	30	06	FE	80	CC	30	06	CD	21	03	C3	FA	03
0440	CD	BF	05	3E	10	CD	0B	03	C3	41	00	CD	24	01	CD	CF
0450	01	CD	C4	04	3A	00	80	21	04	20	01	01	3B	FE	42	CC
0460	A2	04	FE	41	CC	B4	04	2C	06	17	FE	82	CC	A2	04	FE
0470	81	CC	B4	04	2C	01	02	07	FE	22	CC	A2	04	FE	0B	C2
0480	92	04	3E	EE	CD	DE	05	21	CE	07	11	0E	40	0E	33	C3
0490	E8	06	7E	32	06	40	2D	7E	32	04	40	2D	7E	32	02	40
04A0	AF	C9	7E	CD	A9	04	77	AF	C9	B8	DA	B1	04	79	D6	01
04B0	C9	C6	01	C9	7E	CD	BB	04	77	AF	C9	B9	F2	C1	04	78
04C0	C9	D6	01	C9	3A	06	40	07	07	07	07	E6	F0	F6	0D	2E
04D0	05	CD	AF	02	AF	C9	CD	E9	05	E5	CD	18	07	3A	00	80
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04F0	E1	E5	7E	E6	07	57	01	01	05	3A	00	80	FE	42	C2	09
0500	05	7A	CD	A9	04	57	C3	13	05	FE	41	C2	13	05	7A	CD
0510	BB	04	57	CD	32	07	E6	F8	B2	77	3A	00	80	FE	02	C2
0520	32	05	E1	E5	7D	C6	19	6F	7E	3C	E6	03	47	7E	E6	FC
0530	B0	77	FE	20	C2	40	05	21	13	20	01	01	17	CD	A2	04
0540	FE	08	C2	56	05	E1	E5	3E	C0	77	CD	DC	05	CD	21	03
0550	3E	FF	32	18	20	AF	FE	30	C2	82	05	3A	13	20	FE	12
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0570	F0	FE	00	C2	78	05	3E	20	47	3A	26	40	E6	0F	B0	32
0580	26	40	E1	E5	3A	05	20	FE	18	CC	DC	05	C4	CF	01	CD
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05B0	07	F6	40	CD	FC	02	3A	18	20	FE	FF	CC	BF	05	C9	AF
05C0	32	18	20	21	0E	40	CD	F2	05	21	14	40	CD	F2	05	21
05D0	1A	40	CD	F2	05	21	20	40	CD	F2	05	C9	3E	0C	21	00
05E0	60	77	23	77	23	77	23	77	C9	21	0E	40	3A	13	20	85
05F0	6F	C9	7D	5D	C6	05	4F	68	46	23	7E	B8	DC	07	06	7D
0600	B9	CA	28	06	C3	F8	05	70	2B	77	23	E5	7D	C6	18	6F
0610	7E	E6	03	47	7E	90	57	23	7E	E6	03	B2	2B	77	23	7E
0620	E6	FC	B0	77	E1	16	01	C9	AF	BA	CB	16	00	C3	F7	05
0630	21	27	40	FE	80	C2	3A	06	2E	33	3A	13	20	B5	6F	7E
0640	47	E6	FC	0F	0F	32	14	20	3A	0A	20	FE	80	78	C4	F2
0650	06	CC	F9	06	E5	CD	6F	02	CD	36	02	FE	20	D2	62	06
0660	EE	F0	CD	AF	02	32	18	20	3A	00	80	FE	20	C2	7D	06
0670	21	13	20	01	01	0B	CD	A2	04	E1	C3	D2	06	21	14	20
0680	01	01	3E	FE	02	C2	92	06	CD	A2	04	E1	CD	D4	06	C3
0690	D2	06	FE	01	C2	A1	06	CD	BC	04	E1	CD	D4	06	C3	D2
06A0	06	FE	10	E1	C2	D2	06	E5	21	13	20	01	01	0B	CD	A2
06B0	04	CD	36	02	FE	20	D2	BB	06	EE	F0	CD	AF	02	47	3A
06C0	18	20	B8	E1	C2	D2	06	23	E5	CD	D4	06	CD	21	03	C3
06D0	A8	06	AF	C9	3A	14	20	07	07	47	7E	E6	03	B0	77	C9
06E0	21	C0	07	11	00	40	0E	40	7E	12	23	13	0D	C2	E8	06
06F0	AF	C9	E6	FC	0F	0F	C6	42	C9	E6	FC	0F	C6	77	C9	D6
0700	42	07	07	E6	FC	47	7E	E6	03	B0	77	C9	DE	7F	07	E6
0710	FC	47	7E	E6	03	B0	77	C9	7E	47	E6	F8	0F	0F	0F	32
0720	05	20	78	E6	07	47	AF	0E	0A	80	0D	C2	29	07	32	04
0730	20	C9	3A	04	20	1E	00	FE	0A	DA	42	07	1C	D6	0A	C3
0740	37	07	3A	05	20	07	07	07	E6	F8	B3	C9	21	00	00	06
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07A0	48	5D	68	88	FF	63	00	01	07	FE	00	CA	B0	07	F6	08
07B0	6F	3A	0A	20	C9	FF	FF	20	4E	4F	56	20	31	39	38	35
07C0	00	22	00	35	00	16	01	01	01	01	0F	06	00	80	3B	4B
07D0	60	70	88	98	33	48	60	6B	83	9B	38	4B	60	70	88	98
07E0	33	48	60	6B	78	9B	63	33	7A	63	72	6B	82	33	7B	5B
07F0	70	4B	7A	37	72	4B	72	4B	72	37	70	4B	70	4B	72	BB

Listing 1 Hex dump of the EPROM software.

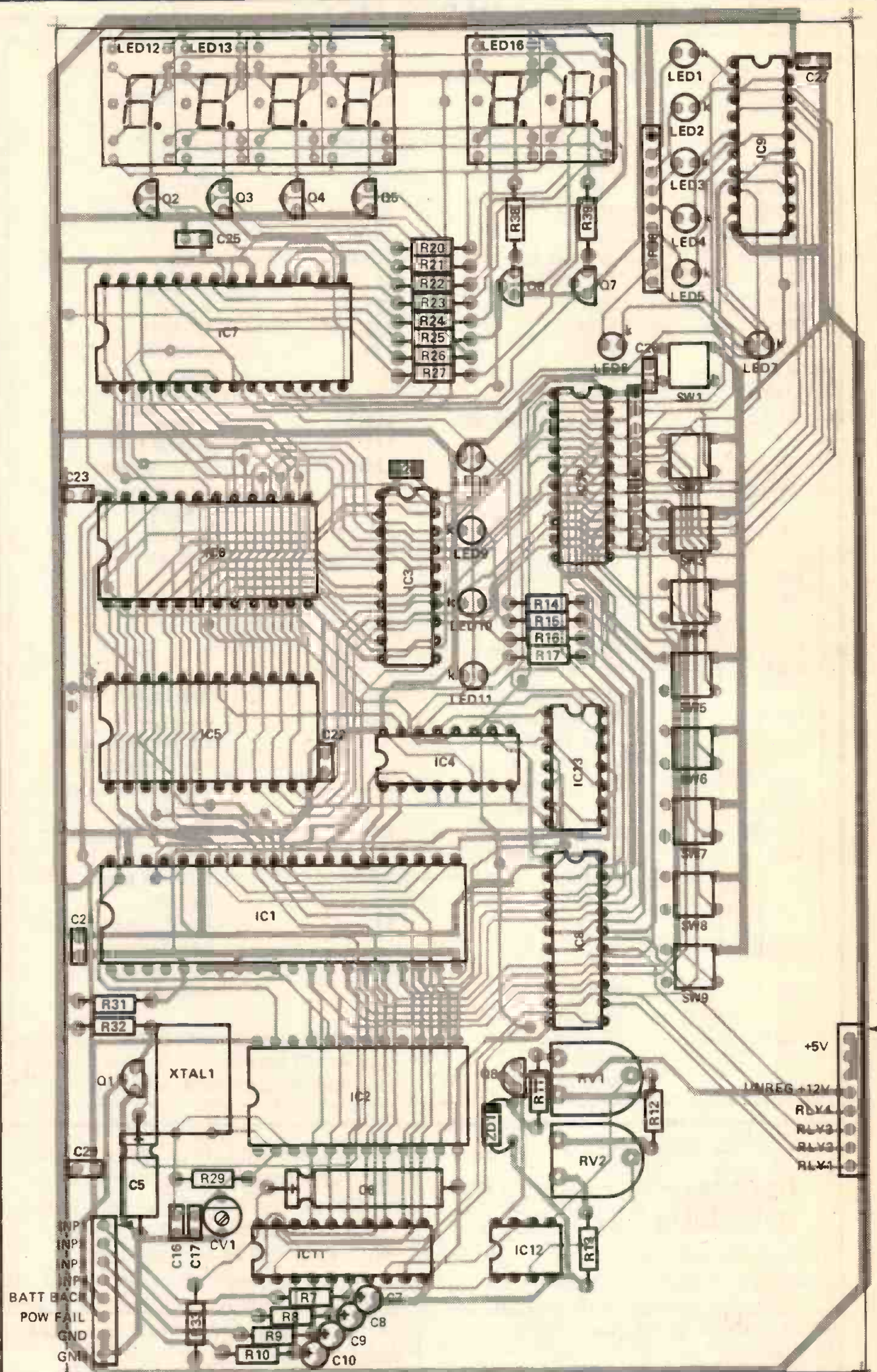

Fig.5 The component overlay of the main board.

The time and temperature measured by the three sensors can be displayed in Run mode by pressing the relevant button.

In Set mode the function being set is indicated by one of the four LEDs to the left of the buttons. You can advance to the next function by pressing the FUNCTION button.

The Time

With the top function LED lit, the time may be set by pressing the HOUR, MIN, and DAY/PROG Buttons in turn and using the ⇧ and ⇩ buttons to increase and decrease the time displayed.

Pressing the FUNCTION button will enter the time and move on to the program function.

Program Times

The program times for each day are numbered 1 to 6 and the programmable days are labelled 1 for Sunday, d for the weekdays, 7 for Saturday.

Step through each program for each day using the DAY/PROG button. Set the time for each

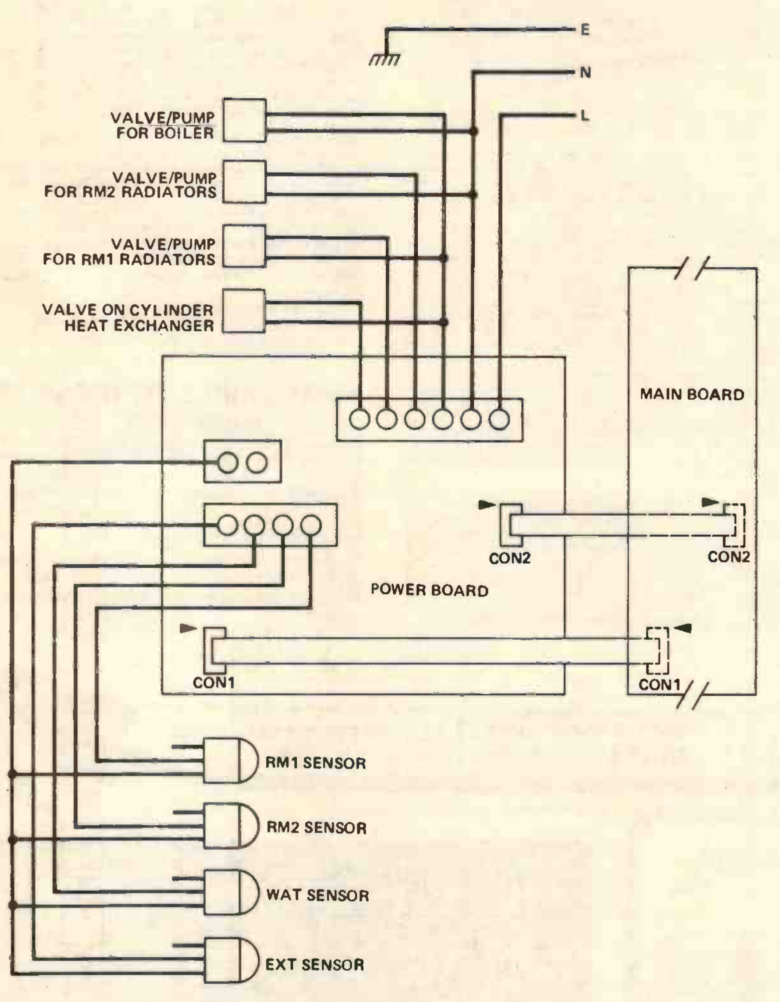

Fig.6 Interconnecting the PCBs and installing the system.

program event in the same way as the time of day is set (note, however, that the minutes is now advanced in ten minute steps). The action at the time set is programmed by pressing the STEP button until the HW AVAIL and CH AVAIL LEDs indicate the desired action.

The program is set when the DAY/PROG button is pressed to move to the next program. The process is repeated for each set of six programs for each programmable day. Programming the floating day is the same except that the day the floating day is to replace is set with the COPY button. Press and hold the COPY button and press the DAY/PROG button until the day number required is displayed.

If all six programs for any programmable day are not required the unwanted programs can be deleted by pressing the CANCEL button. The display shows CCCC for a short period and the remaining programs are moved down to take up the space. CCCC is displayed for the time of any such cancelled programs.

There is no need to enter program times in chronological order. The software sorts them.

Program Temperatures

The weekend (E) room temperatures are set first. For each period the set temperature is displayed and can be altered using the ⇧ and ⇩ buttons. The DAY/PROG button sets the temperature and advances to the next period. After all six periods have been programmed the DAY/PROG button moves onto the weekday (d) room temperature periods.

The water temperature is set next and in the same way as the room temperatures.

To save time, the COPY button can be used to copy the current temperature settings to the following periods for that day.

The preset times and temperatures can be set at any time by pressing CANCEL, ⇧ and ⇩ at once in Set mode.

Overrides

Pressing the ADVANCE button allows the control of the central heating and hot water by the timer to be overridden until the next programmed time event. The STEP button and the CH AVAIL and HW AVAIL LEDs are used to set which function(s) remain under the timer control.

The OVERRIDE button is used in the same way but the manual setting remains until cancelled by using the OVERRIDE and STEP buttons to return control of both the hot water and central heating to the pre-programmed sequence.

The HW BOOST button will switch on the hot water (say, for a bath) until the temperature reaches the current period temperature when it shuts off to follow the normal program.

Locking

The controller can be locked by pressing and holding the HOUR and OVERRIDE buttons together for a few seconds. Locking is indicated by the RUN LED going off. To unlock the controller, press the ADVANCE, STEP and OVERRIDE buttons together for five seconds.

ETI

BUYLINES

Most of the components should be available from usual sources. The suppression capacitors (C12-15) are available from Maplin.

The EPROM (IC15) is available ready programmed from the author for £10. Please address all orders and enquiries to Harry Bloomfield, 49 Oak Crescent, Garforth, Leeds LS25 1PW. The PCBs are available from the ETI PCB Service.

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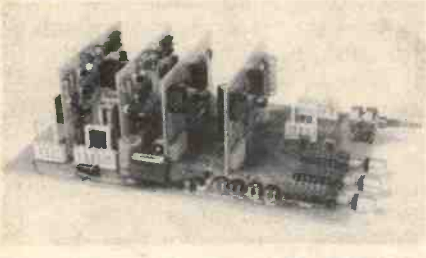

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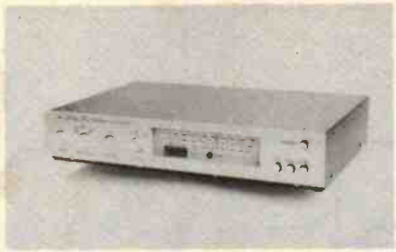

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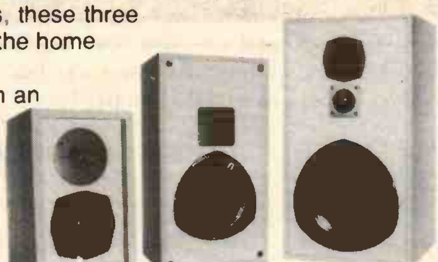

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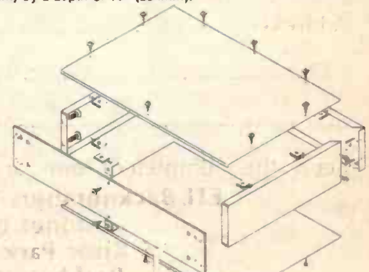

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THE DREAM MACHINE

Paul Chappell puts the free components on this month's cover to good use with a description of the construction of the ETI Dream Machine.

Last month I spoke of dreams in general and described the basic principle of the Dream Machine. You should also have collected your free PCB from the cover. Now that you have the components too, it's time to start on the construction.

You will have to decide before you start whether you want to build the simple version or the complete project because the component layout is slightly different for each.

The simple circuit will give you a taste of the possibilities of the Dream Machine without spending any money! It can be built entirely from the ETI free gifts. The circuit diagram for this version is shown in Fig.1. You will need to feed the output into your hi-fi amplifier to make it audible. Figure 2 shows how to lay out the components on the PCB and how to connect the circuit to your amplifier. The circuit is powered from a PP3 9V battery.

The extended Dream Machine circuit is shown in Fig.3. This version is a completely self-contained project with its own mains power supply, amplifier, speaker and controls. Figure 4 shows the component layout for

HOW IT WORKS

The simple version first (Fig.1). This really is simple! The zener produces noise voltages which are buffered by Q1 and amplified by a factor of about 2½. The capacitor gives a gentle roll-off to the higher frequency components and the output is fed to an external audio amplifier.

The complete Dream Machine (Fig.3) is similar in principle but allows variation of the volume and depth of the sound and also allows the circuit to be trimmed for maximum output. RV1 sets the operating conditions for ZD1 to allow it to produce maximum output. Q1 amplifies the output considerably and RV2 adjusts the steepness of the high frequency cut-off. IC1 amplifies the sound and drives the loudspeaker.

The voltage gain of IC1 is set by R4. C6 cuts the gain of the amplifier at high frequencies to keep it stable. R5 and C9 make the load on the amplifier 'look' more resistive at high frequencies which helps the transient response and the stability. IC2 is a voltage regulator to provide a fixed 12V supply to the circuit.

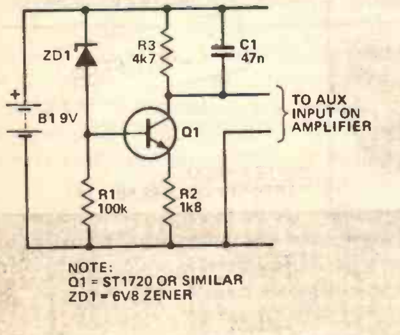


Fig.1 The circuit diagram of the free Dream Machine.

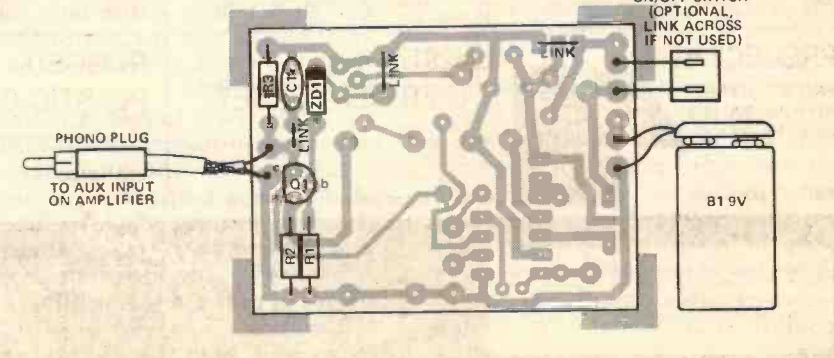


Fig.2 Component overlay for the free Dream Machine.

PARTS LIST

RESISTORS (all ¼W 5%)

R1	100k *
R2	1k8 *
R3	4k7 * (not required for complete project)
R4	47R
R5	1R0
RV1	500k horiz. preset
RV2	4k7 log pot
RV3	10k log pot

CAPACITORS

C1	47n ceramic *
C2	2µ2 16 V radial electrolytic
C3,5	100µ 16V axial electrolytic
C4	4µ7 16V radial electrolytic
C6	220p ceramic
C7	47µ 16V radial electrolytic
C8	220µ 10V axial electrolytic
C9	220n 16V tantalum
C10,11	10µ tantalum 16V
C12	2,200µ 25V electrolytic

SEMICONDUCTORS

IC1	TBA820M
IC2	7812
Q1,2	ST1720 or equivalent
ZD1	6V8 400mW zener*
D1-4	1N4001

MISCELLANEOUS

FS1	500mA fuse and fuse holder
LP1	neon and current limiting resistor
LS1	50R ¼W 2½in loudspeaker
T1	12V 6VA mains transformer
SW1	SPST mains switch

PCB*; case; knobs; mains flex; cable clamp; screened wire; adhesive pads.

* Components supplied free with this issue

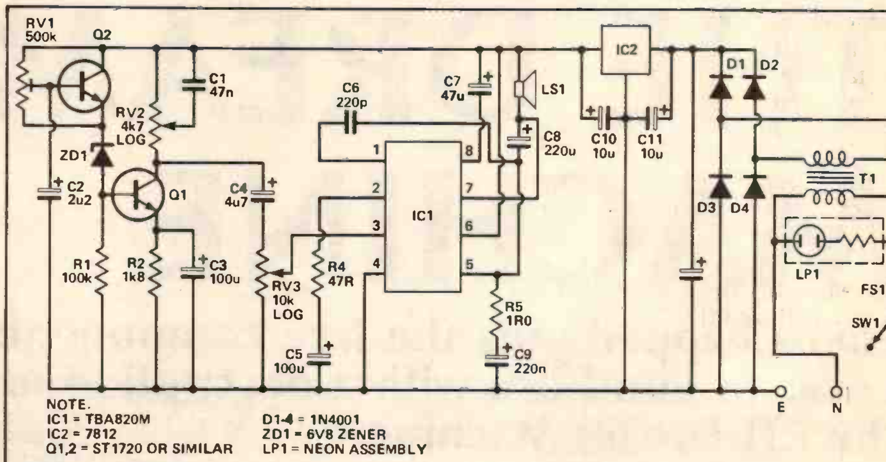


Fig. 3 The circuit diagram of the extended Dream Machine.

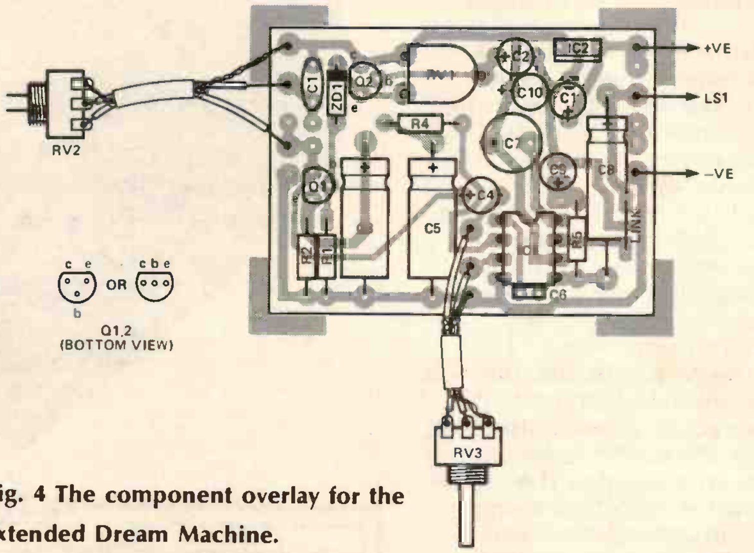


Fig. 4 The component overlay for the extended Dream Machine.

this version and Fig.5 shows a suggested layout for the entire project.

For the prototype we used a case with plastic front and rear panels. It makes the drilling easier and saves the bother of earthing metal panels (which is important in mains powered equipment — even the best made project can go wrong!). The holes for the pots, switches, neon lamp and fuseholder were made by drilling small holes in the correct positions and then widening them out with a reamer.

Reams And Reams

The reamer is such a boon and a blessing to mankind that I feel inspired to say a few words about it, just in case there are any beginners amongst you who are still hacking cases about with a kitchen knife.

A reamer is a gently tapered steel cone with sharp fluted protrusions (I don't know what that means but it sounds good!) The theory is that if you haven't got a drill bit of quite the right size, you can drill a hole to the next size smaller, put the reamer in the hole and twist a few times to widen it a little.

What really happens is that you sort through your drill bits, discarding the one that got bent in the tragic carpentry accident, the one that got stuck in the wall and now has a picture hanging from it and the ones that are too blunt to drill cheese until you are left with a single $\frac{3}{16}$in bit. You drill every hole with this bit and widen them all out with a reamer! Full details can be found in the ETI workshop manual, to be written as soon as I find my biro!

Reamers come in two types. Some have a handle like a screwdriver, others have a shaft with a hole in it. A bar through the hole gives enough leverage to tackle quite substantial thicknesses of metal.

Either type will munch its way through plastic at high speed but on thick sheets of aluminium the difference in blistering ratios and sore finger index becomes noticeable. Any of the larger electronics catalogues will have reamers in the tool section, so if you haven't already got one — buy one today!

Making a reasonable looking hole for a loudspeaker is always a problem. Some people drill rows of small holes and glue the speaker underneath. It works OK, but looks very home made. This might be a great selling point for Mr Kipper's cakes, but it's definitely to be avoided in electronics projects.

For this project I did the bare minimum of work to make it look reasonable. The 1½in hole was made with a hand operated sheet metal punch — the type with two halves that gnash together under the pressure of a nut running along a screw thread and take out a neat circle of plastic in the process. Underneath the hole is a piece of aluminium mesh from the local hardware shop and beneath this the loudspeaker is glued with araldite.

Araldite holds the mesh in place too. On another occasion I tried melting it into the plastic of the case but the mesh was such a good heatsink that the whole case was hot and soft by the time it started sinking in. The result looked something like Dali's liquid watches!

It surprises me that nobody seems to have thought of making a stick-on loudspeaker trim as a standard component. Perhaps they have and I just haven't come across it! Ideally it should stick to the top of the case and have very fine holes. That way you could make a complete pig's breakfast of the drilling without anybody ever knowing!

The transformer should be fixed to the case with suitable nuts and bolts. The smoothing capacitor can be glued to the case or held in place with a double sided self-adhesive pad. The rectifiers are wired directly between the transformer and capacitor, avoiding the need for veroboard or another PCB for the power supply. Figure 5 shows two ways to do this depending on whether you choose a can type electrolytic or an axial type. Radial electrolytics can be wired in the same way as the can types, with the leads bent into a circle to give a little extra support to the solder joints. The rectifier leads should be insulated — you can use lengths of insulation stripped from the mains wire to do this.

Two double-sided self-adhesive pads will hold the PCB in place firmly — it's not heavy enough to break loose. Screened wire should be used for the connections between the PCB and the pots. The speaker connections can be made with ordinary connecting wire.

Testing

Before switching on, make sure there is a suitable fuse in the fuseholder and check the mains wiring carefully. Set the preset RV1 and both pots to mid position. Switch on the Dream Machine and if all is well you should hear a soft hiss from the loudspeaker.

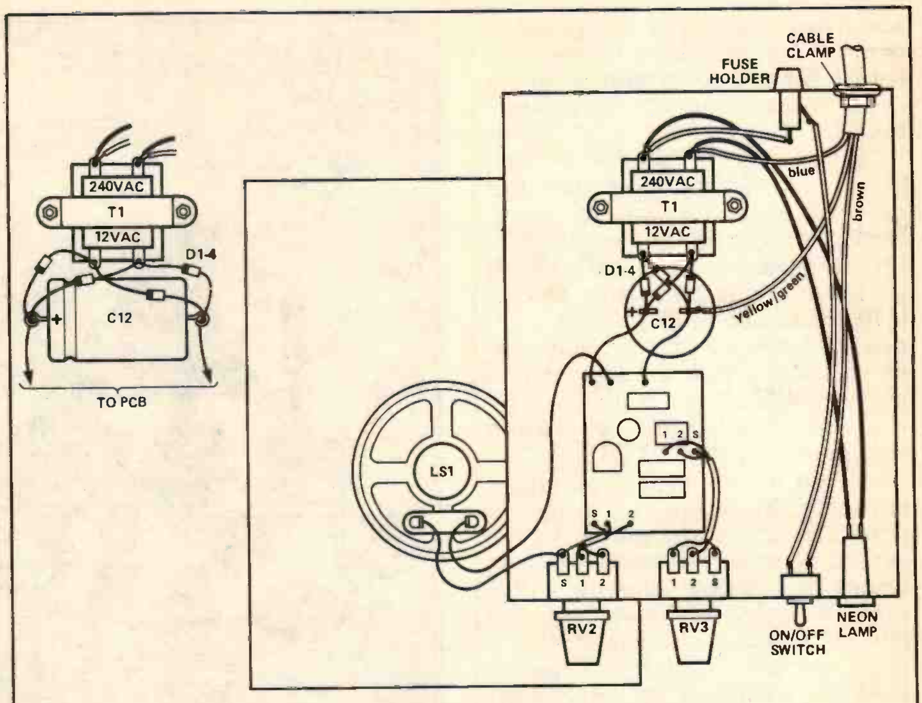


Fig. 5 Wiring up the extended Dream Machine.

If the speaker makes any other kind of sound, switch off immediately.

If there is no sound at all from the loudspeaker, check that the neon lamp is lit. If not, turn off and check the fuse and mains wiring again. If the neon is lit, check with a multimeter that there is about 17V across the smoothing capacitor C12. If not, check the power supply components — in particular, make sure the rectifiers are the right way round.

If all is well so far, check that there is a 12V supply to the PCB, regulated by IC2. The most convenient place to make this check is between the 'screen' connections of the two pots with the negative lead of the meter to the right-hand terminal of RV3 and the positive lead to the left-hand terminal of RV2.

The meter should register a voltage of almost exactly 12V. Too high a reading will almost certainly indicate a damaged regulator or a dry joint on the central pin of the regulator (IC2). Too low a reading and a very hot tab on the regulator will indicate either a solder short somewhere on the board or that IC2 is damaged. In either case, turn off before the circuit catches fire!

If all tests so far are OK, check that the regulator is running cool (the tab should be barely warm to the touch) and see if you can bring on the sound by adjusting RV1. Turn it slowly from one end of its travel to the other. If there is still no response, touch a damp finger to the central pin of RV3. A loud hum in the loudspeaker will show that IC2 is working!

Any further testing should be carried out with the PCB removed from the case to avoid any possibility of contact with the mains wiring. If the 'finger test' gives no response from the amplifier, remove lead 1 (Fig.5) from RV3 and try again. If it still doesn't work, the amplifier section of the circuit is at fault.

Touch IC1 to see if it is getting hot. If not, you can make some voltage checks to pinpoint the area of the board where the trouble lies. Connect your meter between pins 4 and 6 of IC1 (– to pin 4, + to pin 7) and check that it reads 12V. Check that the voltage at the positive end of C8 is also 12V (if not, check the speaker connections).

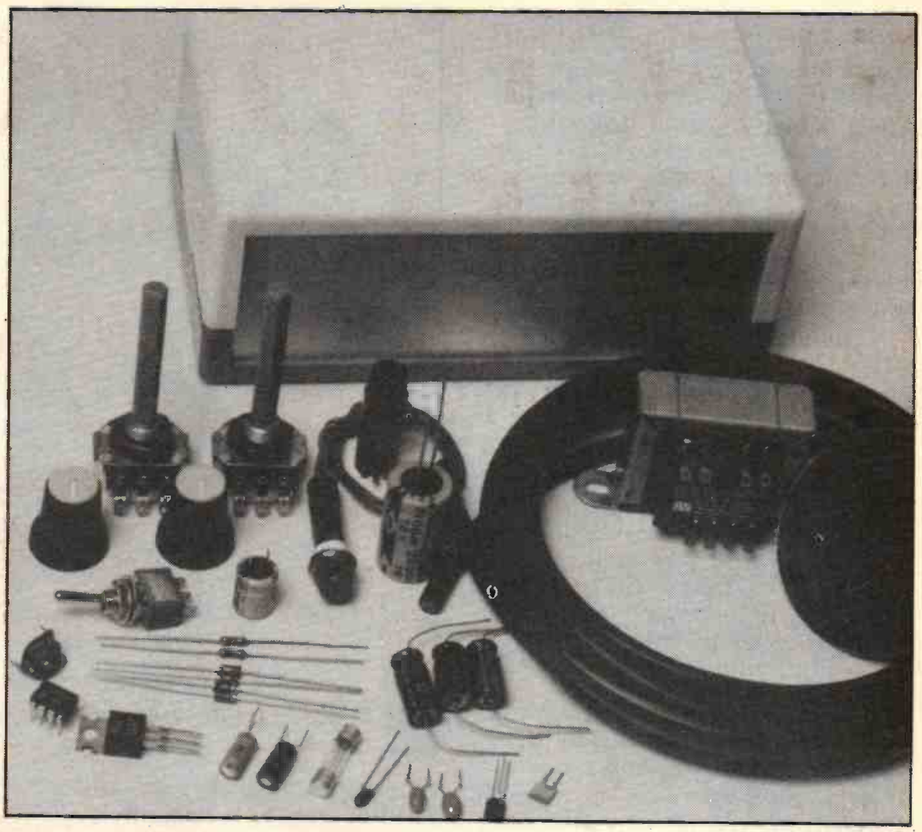
Check the voltage at IC2 pin 5. It should be 6V. If not, short pins 3 and 4 of the IC together. If this cures it, check the connections to RV3. If the fault remains, leave the short in place and remove one end of C7 from the PCB. If this brings the voltage on pin 5 to 6V, C7 is faulty and should be replaced. If not, replace the C7 connection and remove one connection of C5. Once again, if this cures the fault, replace C5, if not, put the connection back. Do the same for C6.

If none of this works, you can reasonably conclude that IC1 has been damaged and replace it. If you are not entirely confident about your soldering technique, it would be a good idea to use a socket for this IC, which is the most delicate component on the board.

If the amplifier section of the board is working (finger hum, but no hiss), check the voltage between collector and emitter of Q1. This should be at least 1.5V. If it's more, it doesn't matter. If it's less, try adjusting RV1. If this doesn't bring it into line, solder a 4k7 resistor across the terminals of RV2 (between S and 2 in Fig.5). If this doesn't help either, check the voltage across R2 and C3.

When the circuit is working correctly, this should be in the region of 2.5V and should vary according to the setting of RV1. Check this out by adjusting RV1. If there is no change in voltage, check the voltage across ZD1 (if that's not 6.8V, the zener is faulty) then the voltage at the emitter of Q2. If this doesn't change as RV1 is adjusted, suspect RV1 or Q2. If it does, but Q1 emitter voltage doesn't, suspect Q1.

The resistor soldered across RV2 can be left in place if it helps. The short between pins 3 and 4 of IC1 should be removed as soon as the tests on IC1 are completed. When all is working, adjust RV1 carefully for maximum volume, then fasten down the lid of the case and prepare for some dream experiences!



Living With Your Dream Machine

Last month I mentioned several dream experiments but I suspect many people will build this project simply with the intention of helping themselves or their family to have a deep, refreshing sleep. The Dream Machine seems to work particularly well with young children who have troubled nights and this in itself can help the rest of the household to have an unbroken sleep!

With the Dream Machine by your bedside, adjust the volume and depth controls to suit your mood, then lie back and concentrate on the sound. After a while it will start to become almost hypnotic. Constantly changing, yet always the same. (How's that for a Zen paradox?) Very soon you will find yourself being carried away on waves of sound until you have no choice but to drift into a deep, relaxing sleep.

One of the many paradoxes of sleep is that it is not always a time of relaxation. You notice this in yourself by finding it difficult to get up in the morning — you stumble out of bed still half asleep and feeling as if you've spent the night doing *Circuit Theory* problems or wrestling with alligators. In others it shows itself by restless movements — kicking off the bedclothes, muttering and thrashing about, snoring and grinding teeth.

Morning is the time you really notice having the Dream Machine. When you wake up and actually *want* to get out of bed, when you feel bright and alert and when you don't fall asleep on the way to work, you know you've slept properly. It can be quite an astonishing experience the first few times it happens!

Once you've got used to having the Dream Machine by your bedside, you can concentrate on some of the dream experiences I mentioned last month. Lucid dreams, where you have complete control over your dream actions, can be very exciting. Just think of all the things you've ever wanted to do. . .then go ahead and do them! You can't die of dreaming or be arrested for it. Nobody will gossip about it because only you will know!

The only way to bring on a lucid dream is simply to decide to have one. This is easier than it sounds. The chances are that after a few nights you'll find yourself in the middle of a dream and think to yourself 'I'm dreaming. I can do anything I like!'.

Surprisingly enough, this is most unlikely to wake you up. You'll probably find at first that you can keep control for a few minutes at a time before forgetting what you're doing and drifting back into a normal dream. With a bit of practice you'll be able to keep it up for longer and longer. The experience is likely to be on the surreal side — if your ambition is to rob a bank, you may find yourself removing sacks of eels or doughnuts from the vaults. Never mind. Try again tomorrow night! **ETI**

BUYLINES

All components for this project are readily available from any component supplier except possibly for IC1. If you have difficulty in obtaining this component it can be supplied by Specialist Semiconductors for £1 inclusive of postage and VAT (see the ad in this issue). A complete parts set including case, transformer, and all fittings and components, to expand the free gift components into the complete Dream Machine will be available from our Readers Services department. Look out for the ad in this issue for full details.

If you missed last month's issue and your free PCB, you can obtain a copy (if you're quick!) by sending £1.90 to Infonet Ltd., Unit 5, River Park Industrial Estate, Billet Lane, Berkhamsted, Herts HP4 1HC. Please be sure to let them know it's ETI you want, and tell them which issue.

ELECTRONIC VIOLET

Ronald Alpiar describes a novel instrument of the violin family you can build yourself.

Now that electronics and computers have so astronomically broadened our musical horizons, it may be time to pause for a moment and consider what we really require of that elusive creature, the ideal musical instrument. Maybe we should ask ourselves whether the almost ubiquitous keyboard is really the only, or even the best answer to a musician's prayer?

This article will introduce readers to a novel breed of musical device which can be constructed by the average handyman at trifling cost — given a BBC micro with the Music 5000 add-on.

A host of desirable qualities might be required of the ideal musical instrument, ranging from beauty of appearance to low cost. Concentrating on purely musical factors I'd narrow it down to three criteria — Ease, Versatility and Intimacy. Let's consider these in turn.

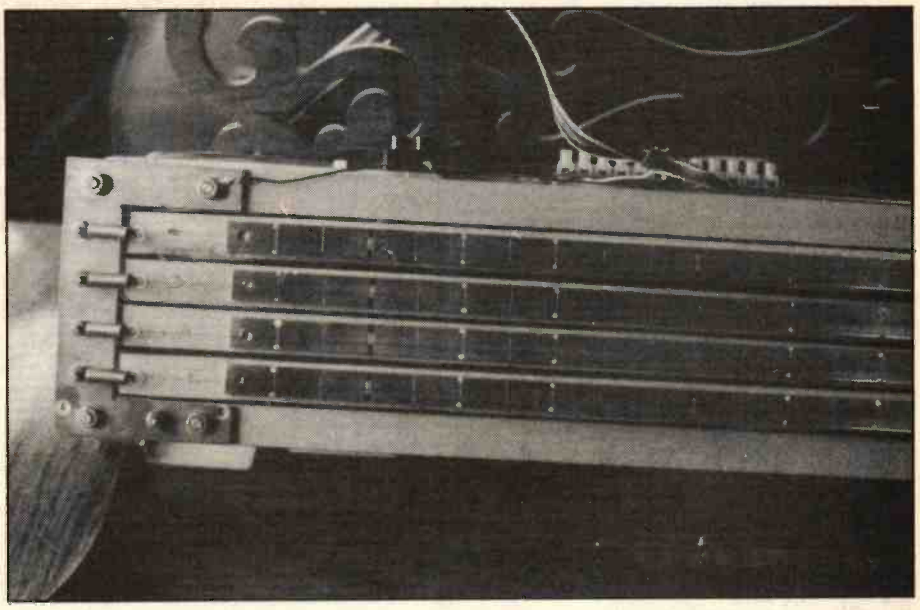
Ease

The instrument should not be so insuperably difficult to perform as to deter all but the most stouthearted. It should be possible to acquire a commendable technique without superhuman effort, and demand no rare inborn gifts of the performer. Portability may also be a consideration — past are the days when every household boasted a piano in its parlour!

At the same time the opposite extreme should also be avoided (an instrument which requires absolutely no training or practice) since these disciplines are needed to develop musicianship as well as technique.

Versatility

Monotony being the enemy of music, the ideal instrument should be capable of producing a wide range of sounds. This



versatility should include everything from sublime beauty to discordant harshness. It should not only cover the full range of audibility but also be capable of dynamically altering the volume and timbre of a note whilst it is sounding — not merely when it commences. The full range of audible frequencies should be available and every variety of waveform and envelope should be at the performer's command.

Intimacy

Anyone who has thrilled to the performance of Tortellier on the cello or of Julian Bream on the guitar will understand what is meant by intimacy — a mystic marriage between the musician and his instrument.

The performer's movements should be appropriate to the sounds produced — just as if he were conducting an orchestra. Control of sound by the breath is perhaps the most intimate medium — reaching its height of expressiveness in the human voice. Next comes the pressure of fingers and the stroke of the arm. Least intimate of all is the control of sounds by adjustment of knobs, dials, levers and switches. The tendency of more advanced electronic keyboards to incorporate touch sensitivity, despite formidable electronic problems, shows how much importance is attached to the intimacy factor.

So how well do some common instruments measure up to these three criteria? Our comparisons begin with the piano. The instrument is relatively easy to play and the stance comfortable and relaxed. Singlemindedness alone is all that is required to acquire a formidable technique. Touch sensitivity in the keyboard enables individual notes to be accented, rhythms to be established and phrases to be moulded so a fair measure of intimacy is provided, which both organ and harpsichord lack. But this has to be paid for. A pianist must spend many hours of laborious practice to ensure that his audience is not constantly reminded that the thumb is intrinsically more powerful than the little finger!

Many musicians regard the human voice as the most intimate of musical instruments and even a model for other instruments to copy. Unfortunately excellence is within the reach of only those born with exceptional architecture of the vocal cavities and even these favoured few are not excused years of hard training.

If we allow our survey to extend to imaginary instruments, we may turn to the human brain itself. Given careful feedback training some conscious control of the brain's natural EEG rhythms is possible. With the brain's electrical activity interfaced to an audio output device, perhaps one could train oneself to actually *think* music in all its detail without moving a muscle! Presumably this would be the ultimate intimacy. Even if it were possible, control of this instrument would demand mental training at least as intensive as the physical disciplines needed to master any real instrument of music.

Let's come back to earth with the violin family — the violin, viola, cello and bass. Perhaps no other sound can rival the haunting beauty of the violin's G-string played in the upper positions or the voluptuous vibrato of the violoncello. Continuous pitch control provides for vibrato glissando and portamento, all under finger control. The bowing action gives dynamic control of both timbre and volume whilst a note is sounding. Besides this, a number of finger and bowing techniques give added variety: 'pizzicatto', finger harmonics, 'spicatto' (bouncing bow on strings), 'ponticello' (the unearthly sound produced by bowing very close to the bridge), 'col ligno' (playing with the wood surface of the bow rather than with the hair surface) are merely a few special techniques exploited in the instruments' repertoire.

This versatility is bought at a great price. For all its natural appearance under a master's chin, the very stance of violin playing is awkward. Aching arms, sore finger tips, a ricked neck or a locked shoulder can be the first rewards of over-zealous practice. It can take at least a year to learn to produce just one single sustained lovely note!

The very fact that (unlike the piano) the violin is capable of continuous — or analogue — frequency control also makes it all too easy to play out of tune.

INSTRUMENT	EASE	VERSATILITY	INTIMACY
BRASS	♩♩♩	♩♩	♩♩
GUITAR	♩♩♩	♩♩	♩♩♩♩
HARP	♩	♩♩	♩♩♩♩
HARPSICHORD	♩♩♩♩	♩	♩
ORGAN	♩♩♩♩	♩♩♩♩	♩
PERCUSSION	♩♩♩♩♩	♩	♩♩
PIANOFORTE	♩♩♩♩	♩♩♩	♩♩♩
SYTHESISER	♩♩♩♩♩	♩♩♩	♩
VIOLINS	♩	♩♩♩♩♩	♩♩♩♩♩
VOICE	♩♩	♩♩♩	♩♩♩♩♩
WOODWIND	♩♩	♩♩	♩♩♩

Fig.1 Instrumental league table.

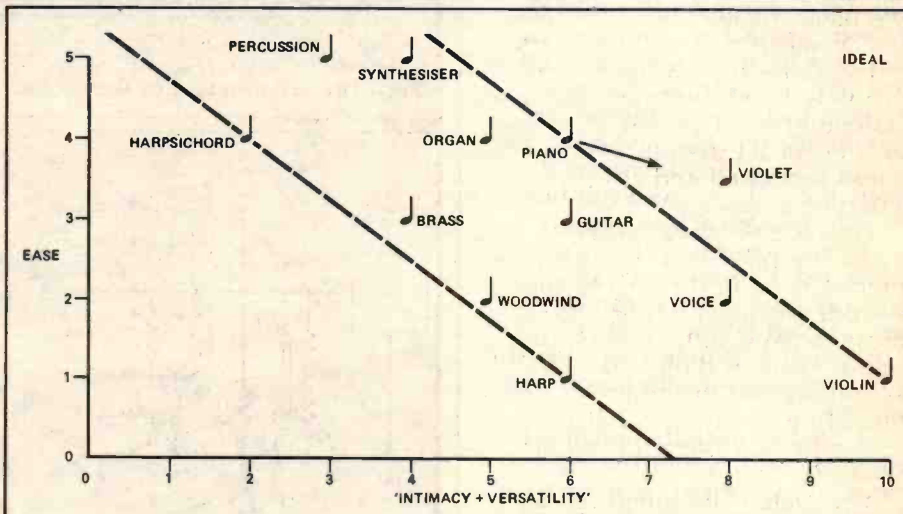


Fig.2 Instrument performance

There are no physical guidelines on the fingerboard. Worse still, the fingerboard's scale is not even linear!

The viola is if anything even more cumbersome than the violin, whilst handling the bass demands some of the qualities of an Olympian athlete. Of the entire family the cello (author's favourite) is the most forgiving and user-friendly. The above mentioned single note can be produced in months rather than years!

By now it is becoming clear that our three cardinal criteria of Ease, Versatility and Intimacy are at odds with each other. An improvement in any one of them appears to bring penalties for the others. The League Table (Fig.1) is of course highly subjective and likely to draw howls of protest. However I believe that the ratings are broadly correct. If we plot Ease against the sum of (Versatility + Intimacy) (Fig.2) existing instruments appear to lie in a diagonal band delimited by the two broken lines, with the ideal instrument well out of bounds.

Maybe we can accept a compromise. I would be willing to consider an instrument which was a *little* harder to play than the piano, provided that it offered continiuous pitch and dynamic amplitude under finger control: but only if it were much easier to play than a cello. The arrow in Fig.2 represents the direction we'd like to move.

These were the thoughts back in the pre-home-computer days of the 1970s when the Electronic Violet (now the flower of nearly a decade of design and development) was conceived. Its design requirements can be stated quite simply:

- A horizontal instrument to be played with both hands in a comfortable, seated position.
- Continuous pitch and amplitude under finger control.
- A linear scale.
- The ability to emulate the performance of each member of the violin family and to address its entire repertoire.

Mechanical Design

Figure 3 illustrates the basic design of the Violet. A resistance wire (called the 'string') is stretched taut above, but not quite touching, a horizontal conducting bar (the 'plate'). The left end of the string is earthed, and its right end is maintained at a stabilised, smoothed voltage V_u (upper voltage). Being of uniform section, the voltage at any intermediate point along the string will vary linearly between 0 and V_u. The instrument is played by pressing the string down onto the plate with the fingertip at some point where the string's voltage is say V_p (pitch voltage). The plate voltage then rises from its idle value of 0V to V_p. Both V_u and V_p enter the BBC micro via channels 1 and 2 of the 4-channel analogue port. The ratio V_pV_u will be used to set the pitch of the sound produced and also to activate gating.

Fine scribed parallel lines across the plate indicate semitone intervals, and further marks may be added to assist the eye to locate octaves, fifths and fourths. Indentations or bumps on the plate (provided they don't interfere with String contact) can be used to aid finger positioning by touch.

The plate is mounted on an insulated wooden lath which floats on a pair of pressure pads at each end. Increasing finger pressure compresses the pads and reduces their electrical resistance. This resistance is converted to a voltage and enters the micro via analogue channel 4 where software converts it to sound amplitude. Both pitch and volume are under dynamic finger control enabling melodies to be played with expression, notes to be accented and finger tremolo to be used.

There are four parallel strings, each with its own independent plate. The four plates are each mounted independently, activating its own pair of pressure pads. In this form the Violet is capable of playing polyphonic music (with up to four voices) opening the door to almost the entire instrumental repertoire.

Interfacing

Before the advent of the home computer, Violet's pitch and amplitude voltages were fed to a bank of four independent exponential-law VCOs and four VCAs. Additional circuitry was used to control gating, to adjust string voltages (and hence tune the instrument) and provide tone control. However, most of this elaborate circuitry can be replaced by the BBC micro.

A smoothed power supply is needed to give a voltage somewhere between 1.5-1.75V for V_u (Fig. 4a). The analogue input accepts voltages between 0-1.8V. The actual voltage chosen for V_u is not critical since pitch is determined by voltage ratios V_p/V_u rather than by absolute values. A value of V_u close to (but not exceeding) 1.8V will improve digital-to-analogue conversion accuracy.

Figure 4a shows the connections of power supply, strings and pressure pads diagramatically. It will be seen that three of the analogue port's four channels are used up with a single string. The multi-string Violet is interfaced by multiplexing channels 1 and 4 as Fig. 4b shows. Each 4016 is simply a bank of four independent single pole switches, each switch activated by its own control pin.

One 4016 multiplexes the V_p from each string to channel 1, the

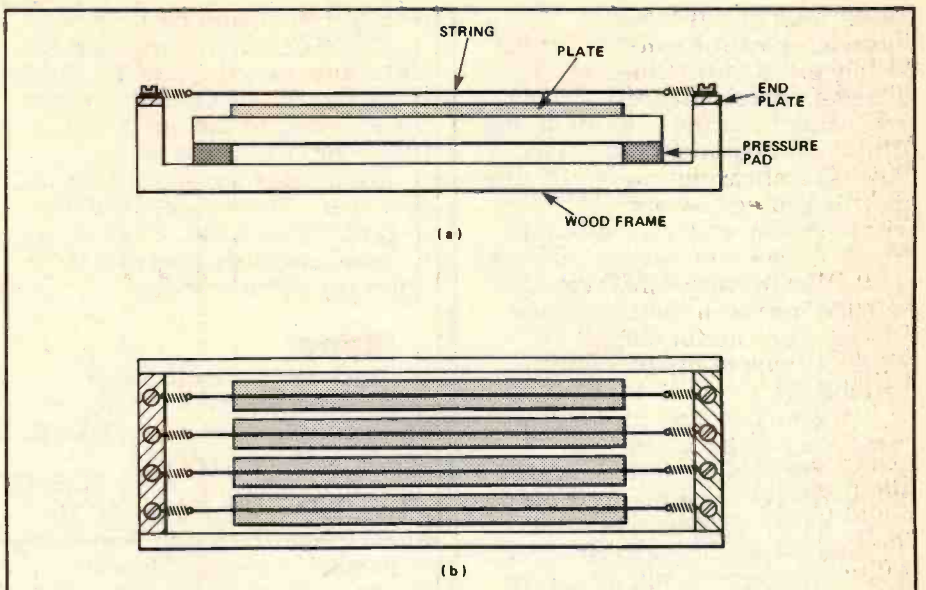


Fig.3 The construction of the Violet.

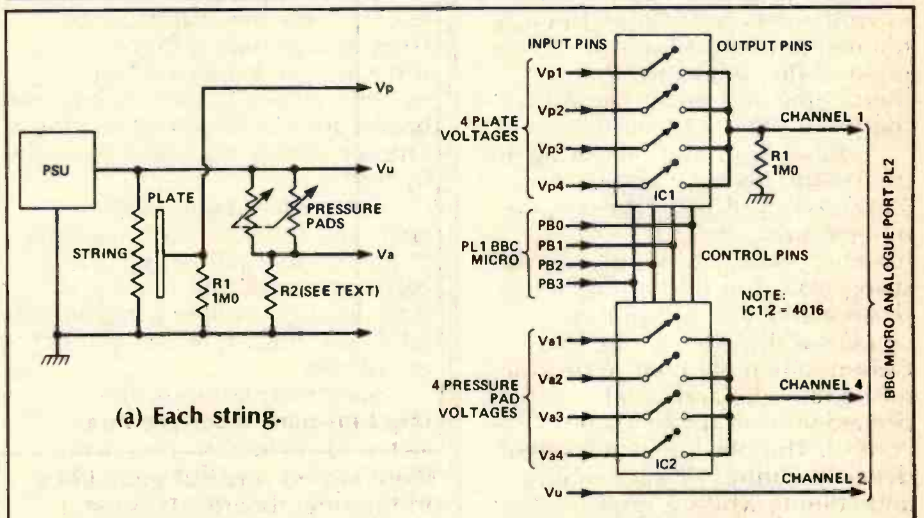


Fig.4 Circuit diagram of the Violet. (b) the multiplexer.

PARTS LIST

RESISTORS (1/4W 5%)

R1,11,21,31	1M0
R2,12,22,23	see text

SEMICONDUCTORS

K1,2	4016
PL1	20-way IDC plug
PL2	15-way D connector

MISCELLANEOUS

PCB or stripboard; pressure pads; plates; wooden frame and laths; resistance wire; springs; end plates; ribbon cable; nuts and bolts.

other multiplexes the four pressure pad voltages to channel 4. Since the four strings are in parallel, V_u can proceed straight to channel 2 without multiplexing. The control pins are connected to bits 0-3 of the 8-bit user port. The port is programmed to continuously change the output states of the four lower user port bits so as to repeatedly scan the voltage messages from the four strings in turn. The whole interface can easily be built on stripboard.

Of course, using this system the Violet could simply be extended to eight strings. With some decoding of the user port lines, 64 strings could be used. However, speed of software and dexterity suggest four strings as the optimum number.

Physical Dimensions

An optimum set of physical dimensions has evolved after much trial and error. The distance between semitones on the Plates is fixed at ¾in. This is roughly the maximum distance between centre lines of two adjacent, almost touching fingers of one hand. So adjacent semitones can be played without the fingers getting in each others' way.

The plates are ½in × ⅛in cross section smooth plane aluminium bars, well polished on the upper surface to ensure clean electrical contact. It is important that the upper surface of the plates do not bend under finger pressure. Each is therefore screwed down onto a planed, seasoned wood lath of ¾in cross section. Strips of copper clad, fibreglass backed circuit board can be used as a substitute for aluminium bars. Each plate is 30in long and so encompasses a full three octaves plus an extra full tone at each end.

The strings extend about 3in beyond the plates at each end. This dead space is necessary, otherwise it would be hard to play lowermost and uppermost notes. The lower deadspace also has a useful gating function. The software can be considerably simplified if the electrical length of the strings is precisely 48 semitones = 36in. An inch or two of loose resistance wire above the rightmost end of a stretched 35in String can be used to trim its effective length. Each string is poised about ⅛in above its contact plate. Too large a separation would require either a slack string or too much finger pressure to ensure clean contact.

However if the strings are too close to plates, the precise contact point can be affected by minute irregularities in the string or upper surface of the plate.

The strings are spaced about ¾in apart. This enables the four fingers of one hand, if necessary, to simultaneously play nearby notes on all four strings.

Strings

The strings should be of uniform resistance wire, free of kinks and notches. I use 34SWG Karma wire (Ni-Cr-Al-Mg quaternary alloy). It has a nominal resistance of 9.52ohms/foot. The total resistance of four 36in strings in parallel is about 7.14ohms. Given a potential of up to 1.8V across the String array, the PSU should be capable of delivering at least ¼A for the strings alone. Finer strings have a higher resistance and demand less current. However, they may be harder for the fingertips to locate. Thicker strings are easier to find by touch.

The contact plates are anchored to 0V via 1M0 resistors to ensure that idle strings are at earth potential. The resistor is large enough to have a negligible effect on linearity when strings are played.

The construction of the pressure pads gives plenty of scope for ingenuity. Pieces of foam rubber moistened in brine work quite well but require regular 'watering' in dry weather and may eventually cause corrosion. Conductive foam used to protect CMOS ICs may also be used. Its slight noisiness under pressure changes can be eliminated by a 1µ0 electrolytic in parallel. At present 1/10in thick pads of a carbon fibre impregnated substance (used in digital weighing machines) are employed. Its resistance varies from about 1000 to 100ohms/cm^2.

Whatever pressure pad material is chosen, it is important that the amount of actual vertical plate movement be minimal. The material should be pressure rather than compression sensitive. It is much easier for the fingers to play steady plates, than ones which keep on bobbing up and down.

The two pads at the extremities of each plate mounting bar are wired in parallel. This helps to ensure touch sensitivity is fairly uniform over the length of the plates. The pads are connected between V_u and 0V via a loading resistor R2. Its value is not critical, something roughly equal to the combined pad resistance at mean pressure will do. The degree of touch sensitivity is in any case under software control, so wide variations in component values can be allowed for.

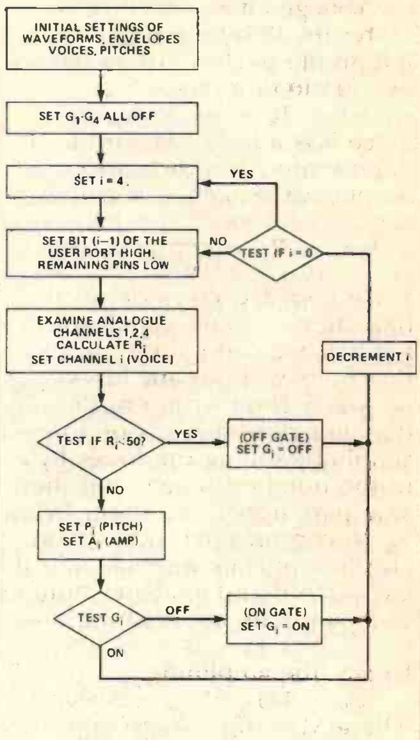


Fig.5 Flow diagram of the Violet software.

The PSU should be capable of delvering 1.8V or less at a maximum of 1A giving generous margins to supply strings and pressure pads. It should also provide for a few mA at about 10V (not critical) to power the switching ICs.

Software

The program which operates Violet has to perform a number of tasks:

- Ensure that ¾in movement on the plates = 1 semitone
- Set relative and absolute tuning of the strings
- Set up suitable amplitude envelopes and waveforms
- Repeatedly scan plates in turn and convert pitch and pressure pad voltages into sounds and at the same time manipulate appropriate gates when a string is initially played or released.

The author's program was written in the Music 5000 programming language, Ample. The overall flow diagram of the software is shown in Fig.5 .

We have already decided that

the voltage change 0-V_u should represent 48 semitones (48*16 = 768 Ample pitch units) so the pitch ratio of a plate:

$$R_i = 768*V_{pi}/V_u$$

Since it is a little awkward to do double precision division in Ample, we actually calculate R_i so:

$$R_i = \frac{(V_{pi}/8) * 3}{(V_u/8)/256}$$

Since the ADC converter in the BBC micro is only significant to ten bits, we can ignore the last three bits without any loss of accuracy. The division of the denominator by 256 is performed simply by setting the lower byte of the number to zero and then swapping upper and lower bytes.

To convert pitch ratios R_i to absolute pitches we must add the bse pitch B and as many multiples of S as we are above string one:

$$P_i = R_i + B + (i-1)*S$$

Finally, the amplitude:

$$A_i = 128 + F*(V_{ai} - M/1000)$$

where M is the voltage from the pressure pads corresponding to an amplitude of 128.

However the formula has to be slightly modified to suit Ample's arithmetic. What is actually calculated is:

$$128 + (F/10)*(C4/455 - M/100)$$

where C4 is the output of analogue channel 4, normalised to an interger in the range 0–8192.

Gating the sounds produced by Violet ensures that notes start and end in a natural way and it is also used to remove any noise caused by uncertain contact when any string is initially depressed and finally released. Gating does not take place when a succession of notes are played on the same string without releasing it.

To perform gating we have to know whether any string is currently active (in contact with its plate) or idle. The plates are anchored to 0V via a 1M0 resistor when idle and to the left of each plate there is a deadspace of about 3in (four semitones = 64 Ample pitch units).

To test whether a string is active or idle it is sufficient to test whether R_i lies between 0 and 64. Allowing for some margin of error in the ADC conversion, in practise we test for $R_i < 50$.

The complete Ample program is given in Listing 1.

```
"POW2" [] "USER" [] "QUSER" []
"ALOG" [] "Ri" [] "GF1" [] "GF2" []
"GF3" [] "GF4" [] "Base" [] "Sep" []
"Mv" [] "Fv" [] "Pi" [] "Ai" []
"Sel" [] "GSOFF" [] "LOOPN" []
"Ns" [] "INIT" [] "PORT" []
"CYCLE" []

"POW2" [1 #12 -1 #+ FOR(2 #*)FOR]
"USER" [256 #* &60 #+ &97 &FFF4 CODE #2
#2]
"QUSER" [&FE60 #B!]
"ALOG" [&80 &FFF4 CODE #2 &8000 #+ 8 #/
#2 4096 #+]
"Ri" [1 ALOG 3 #* 2 ALOG &FF00 AND &B12
#/ #2]
"GF1" [GVAR]
"GF2" [GVAR]
"GF3" [GVAR]
"GF4" [GVAR]
"Base" [GVAR]
"Sep" [GVAR]
"Mv" [GVAR]
"Fv" [GVAR]
"Pi" [-1 #+ Sep #? #* Base #? #+ #+]
"Ai" [4 ALOG 455 #/ #2 Mv #? 100 #/ #2
#- Fv #? 10 #/ #2 #* 128 #+]
"SEL" [#11 2 #> IF(3 #>
IF(GF4)ELSE(GF3)IF)ELSE(1 #>
IF(GF2)ELSE(GF1)IF)IF]
"GSOFF" [OFF GF1 #! OFF GF2 #! OFF GF3
#! OFF GF4 #!]
"LOOPN" [Ns #?
FOR(INDEX VOICE
    INDEX POW2 USER
    INDEX SEL
    Ri #11 50 #<
    IF(OFF GATE #2 OFF)ELSE(
       INDEX Pi PITCHF
       Ai AMP
       #11 ON #12 #? OFF #=
       IF(ON GATE)IF
    )IF
   #12 #!
)FOR]
"Ns" [GVAR]
"INIT" [SOUND #11 Ns #! VOICES -400 Base
#! 112 Sep #! 1000 Mv #! 200 Fv #! GSOFF
PORT CYCLE]
"PORT" [&62 &2711 #B!]
"CYCLE" [REP(LOOPN)REP]
```

Listing 1 The Ample Violet program.

Performance

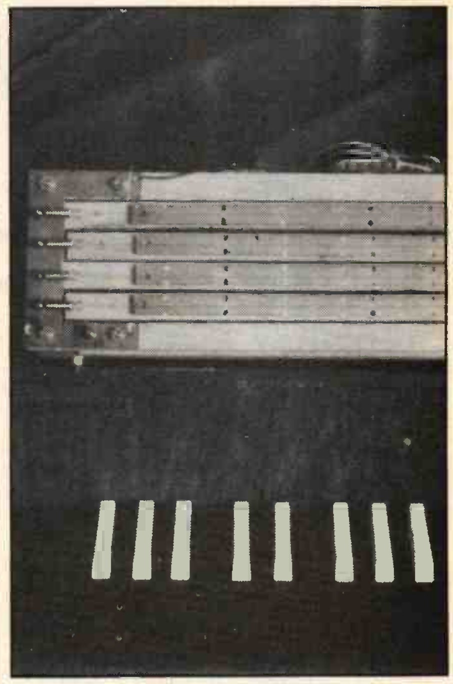
As with any instrument, the player must practise to perform well on Violet. The first difficulty for newcomers is to learn to locate the strings by touch rather than by eye but this skill is surprisingly rapidly acquired.

Finger pressure and vibrato and tremolo finger-tip motion must be practiced. The note sounded can depend both on speed of attack and pressure variation whilst it is being sustained.

Perhaps the main difficulty is inherent in Violet's originality. Unlike established instruments, there is absolutely no body of traditional techniques to guide the learner, no virtuosos or teachers for him to emulate by example. Even the simplest decisions have to be made by you the player. Should you use your thumbs or not? Should the instrument be placed with the lowest sounding string nearest or furthest from the body? Should the plate surfaces be horizontal or tilted? What is the best way of deploying the two hands in difficult passages? All this is till virgin territory, in which each explorer must establish his own familiar acre and homestead.

Other Scales

Almost all Western music is played on an equally tempered scale of 12 semitones to the



octave. This means the pitch ratio of successive semitones is the irrational number $2^{1/2}$. The equally tempered scale is a compromise, which enables music in all keys to be played equally well (or badly).

Ideally successive notes should have frequency ratios of simple fractions, so that chords sound pleasant to the ear. It is mathematically simple to 'retune' the musical scale to one of the 'perfect' pitches, which prevailed before the equally tempered scale was invented. This enables certain Baroque and Liturgical music to be heard as originally intended.

At the other extreme, the standardisation to a 12 note scale has also been called in question. A very thriving school of music with origins in Holland is based on an equally tempered scale of 31 notes to the octave. Music written in this mode has a strange beauty. Again, it is very simple to retune Violet to this type of scale.

So far we have considered an instrument with different strings tuned to different pitches. However they might be all tuned to the same pitch but differ in sound quality, attack characteristics, or even stereo positioning. The potential is all there.

This version of the Violet relies heavily on the BBC micro, the Music 500 and the Ample language. However, many budding Violet players may not have this equipment. Indeed the original Violet was developed as a stand-alone instrument. Next month I shall describe how that universal instrument can be built. **ETI**

SWR AND POWER METER

Andrew Armstrong delves into the depths of aerial matching and designs an SWR meter that leaves other waves standing.

Many people swear by their SWR meters, some people swear at them, but few understand what they really do. I am going to try and unravel what SWR represents and what it does, as well as describing the construction of a stylish SWR indicator intended primarily for CB use.

It is also very suitable for use with 2m transceivers of a few watts output, widely used among radio amateurs. Just one component change is needed to give an accurate 2m SWR indicator.

In using a transmitter it is important to transfer as much of the transmitter's output power as possible to the antenna. The SWR indicator can help achieve this by indicating when the aerial is matched to the feeder.

Power Transfer

To understand why correct matching is important, we will first consider the simple case of a DC voltage source with a source resistance feeding into load resistance, as shown in Fig.1.

Under what conditions does the load receive the maximum power? Common sense tells us that if the load resistance is infinite no current flows and no power is transferred. Equally, a zero load resistance would allow plenty of current to flow but all the power would be dissipated in the source resistance. Starting from the formula:

Load power $= I^2 x R_l$

the following reasoning applies:

$$I = \frac{V}{R_s + R_e}$$

$$\Rightarrow \text{Power} = \frac{V^2 R_l}{(R_s + R_l)^2} = \frac{V^2 R_l}{R_s^2 + R_l^2 + R_s x R_l}$$

$$\text{and if } R_l = R_s \text{ then: Power} = \frac{V^2}{3 x R_l}$$

If you want to get fancy about it you can differentiate this formula and look for a maximum (at which point the differential will be zero). Alternatively you can apply intuition and say that by symmetry it seems that the maximum occurs when $Rl = Rs$.

Calculating the power with some sample values corroborates this. Try $Rs = 50$, and calculate $Rl = 49$, $Rl = 50$, and $Rl = 51$.

The same reasoning applies to power transfer using alternating current, even at radio frequencies. The best efficiency occurs, for example, when a transmitter rated at 50ohms output impedance is connected to an antenna matched to 50ohms with a piece of cable having a characteristic impedance of 50ohms.

The analogy with the DC situation is not perfect. The source impedance need not dissipate the same power as the load or indeed any at all. The impedance refers to a relationship between voltage and current given by the ratio of capacitance and inductance.

Line Impedance

In the case of the coaxial cable, the impedance is the same as the apparent electrical resistance which would be experienced momentarily if a voltage source were connected to the end of a long piece of cable. In Fig.2, if the switch is closed the voltage source charges the inner to outer capacitance of the first infinitesimally small part of the inner core, building up a magnetic field and charging the next part of the cable.

The inductance of the inner prevents the whole of the cable capacitance from charging immediately so it is the value of capacitance compared with the inductance per unit length of cable which will determine what current flows per unit applied voltage. The higher the capacitance, the higher the current.

The current flowing into the cable remains constant for a time.

When the cable is charged to the supply voltage all the way to the end, the current continues to flow in at the beginning just as before. The cable charges to double the supply voltage at the far end and continues to charge to this voltage until the charging point reaches the beginning.

Then, and only then, does any equipment connected to the sending end of the cable get to know about what has happened at the receiving end.

Now current flows back into the voltage source and keeps on flowing until the whole cable has discharged to zero voltage, whereupon the whole thing starts again. That is to say that it would if it were not for the resistance of the cable. Instead of setting up a perpetual system of waves bouncing back and forth, the resistance of the copper wire damps the ringing and the cable settles down to being charged to the source voltage.

The important thing is that until the first ring reaches the sending end of the cable, there is a fixed relationship between the applied voltage and the current which flows. This is exactly what resistance is and the figure measured in ohms is referred to as the characteristic impedance of the cable.

It is that value which, if connected as a resistance at the end of the cable, would have just the same relationship between current and voltage as the cable, so that the source current could flow forever without it being possible to determine from the sending end whether there was a resistance at the far end of a short cable, or instead an infinite length of cable.

This is obviously of no consequence when DC is flowing because whatever the load, it will settle down soon enough. If an alternating current is applied, of such a frequency that the cable represents a significant fraction of a quarter wavelength at the speed of propagation of the wave in the cable, then the matching of the load is important. Instead of having a steady voltage which will settle down in time, the voltage at the sending end is constantly changing and waves are constantly being reflected from the end connected to the load. If the load has the wrong resistance, or is partly inductive or capacitive, then reflection from the receiving end will take place.

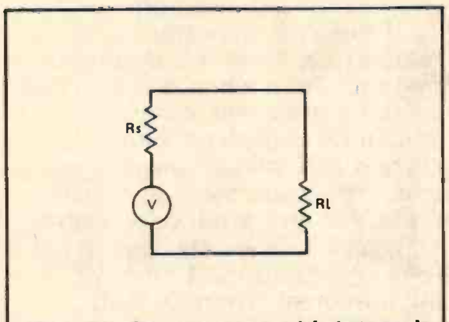


Fig.1 A voltage source with internal resistance feeding a load.

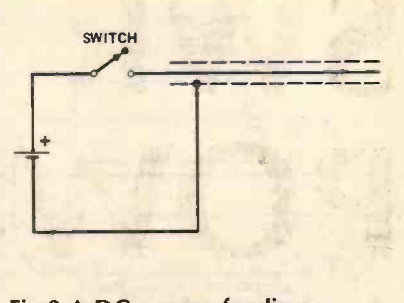


Fig.2 A DC source feeding a co-axial cable.

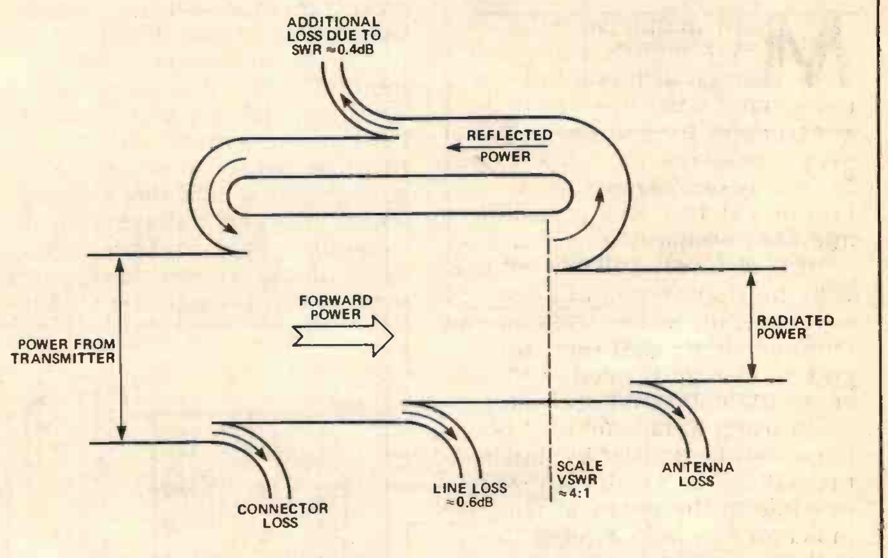


Fig.3 Losses from an imperfectly matched system.

Transmitters

If the signal source includes a resistance equal to the impedance of the cable, the reflected signal will be absorbed in this resistance and wasted. However, most transmitters do not behave like this. Some of the power returned will be absorbed in the output stage but most will be reflected again, back towards the load. The main effect is to increase the peak currents and voltages in the transmitter output stage and risk damaging it.

In this situation, you would expect that in the end most of the transmitter power would reach the load and (if the load was an antenna) be transmitted.

There are two reasons why this is not the case. The first is that there is a loss in the cable as the signal passes through it, both because of the resistance of the copper wire and the dielectric loss. The more passes through the cable made by the signal, the greater the loss. The other reason is that most modern transmitters incorporate circuitry to protect the output stage by turning down the power if too much reflected power reaches the transmitter output.

A moderate amount of reflected power will not discommode the transmitter. If the load matching is reasonable but not perfect then the situation will be as illustrated in Fig.3. The extra loss due to imperfect load matching is very small provided the cable loss is not too large. On the other hand, if the loss is significant then the reflected power measured at the transmitter will be less than that measured at the aerial and the system will appear better than it is.

Standing Wave Ratio

If the antenna is perfectly matched, the voltage and current in the coaxial cable are just as they would be in a resistor. That is to say the current is in phase with the voltage. If the matching is poor and reflection is taking place then standing waves are set up in the cable in the manner illustrated in the thought experiment of Fig.2.

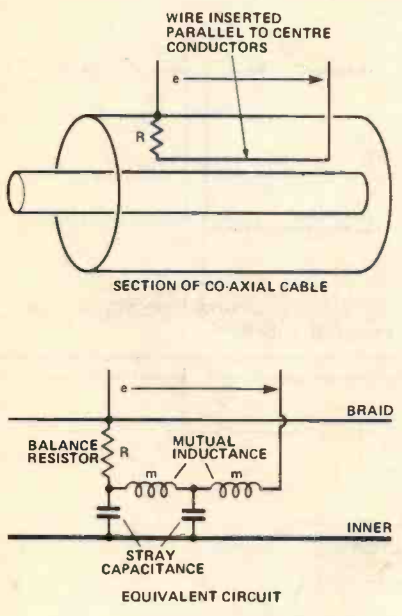


Fig.4 The principle of a conventional SWR meter sensing head.

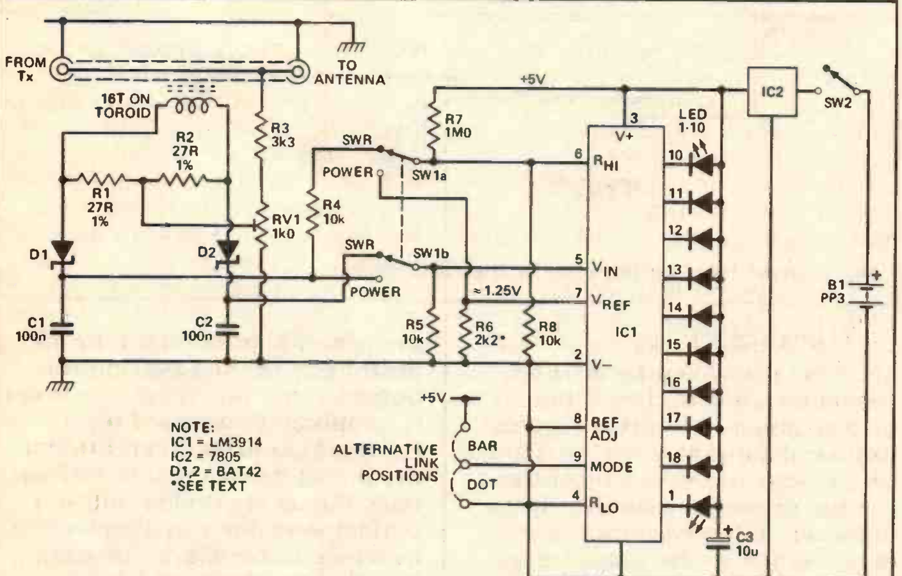


Fig.5 The circuit diagram of the SWR/Power meter.

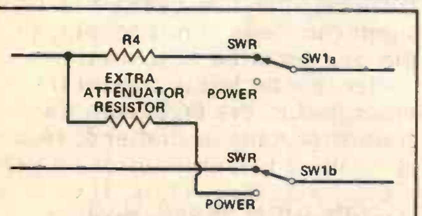


Fig.6 Modification for higher power reading.

The SWR indicator makes use of this by adding or subtracting a signal derived from the cable current to a signal derived from the voltage. If both signals are of the same amplitude then addition will give double the signal while subtraction will give zero.

If the SWR indicator is calibrated to achieve this double or quits situation when no reflection is taking place, the different amplitude and phase of the current and voltage waveforms when reflection takes place will upset this and produce a reading.

Figure 4 shows the traditional form of pickup used for SWR measurement. There is both inductive coupling to detect current and capacitive coupling to detect voltage. If the resistance value is chosen accurately, this pickup method will only detect power flow in one direction.

The disadvantage of this method is that it is frequency sensitive. The use of a broadband current transformer and a resistive divider to provide a voltage signal provides a system which is largely independent of frequency. This principle is used in the design of the sensing head used in this project, the circuit diagram of which is shown in Fig.5.

In this design, the voltage signal is fed into a resistive centre tap in the current transformer circuit. The load resistors are of a low value to load the current transformer so it is operating accurately in a current mode. The current circulating in the loop comprising the current transformer, R1 and R2 is more or less proportional to the current in the inner of the coaxial cable which passes through the middle of the toroidal transformer. The voltage developed across the resistors is not sufficient to interfere with this.

By the same token, the voltage across R1 and R2 is not very large and the forward voltage drop of ordinary silicon diodes would prevent any reading from being obtained at moderate power levels.

To enable the unit to work at the power levels encountered in legal CB equipment, low capacitance Schottky diodes are used to rectify the RF output. Even with Schottky diodes to rectify the RF, the efficiency of the detection circuit is lower at power levels under about 0.5W, so that measurement of SWR with the CB transmitter switched to the low power position is not accurate. This should not be a problem, though, because the SWR of an antenna will not change when the power is reduced, so if it is OK on high power it will be OK on low power too.

Capacitive Shield

To prevent the current transformer from picking up a voltage signal capacitively, the toroidal transformer is slipped over a piece of co-axial cable, with the braid still intact. The braid is grounded at one end so that it provides capacitive shielding. The other end is left unconnected. If it were connected it would form a shorted turn and prevent inductive pickup as well.

There is an added bonus from the capacitive shielding. The legal requirement for CB is that radiated harmonics are of extremely low level. Some types of SWR indicator can generate significant harmonic output just as a result of the internal diodes rectifying the RF. This design has a higher impedance display than types with a moving coil meter, so that less current flows in the diodes. Still, some harmonic output *will* be generated and the capacitive shielding effect of the braid helps to prevent this reaching the aerial.

The components used on the prototype are suitable for power levels up to about 50W. If the sensing head is required to be used at higher power levels, then a higher wattage resistor should be used for R3.

The output from the sensing head is fed to the display via a miniature stereo jack and a three core cable. The prototype used three core miniature mains lead for this purpose.

The display itself uses an LM3914 bargraph IC (IC1). It is

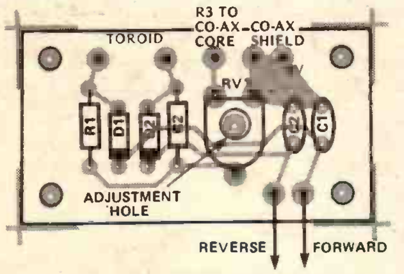


Fig.7 The component overlay for the sensing head board.

PARTS LIST

RESISTORS (all ¼W 5% unless otherwise stated)

R1,2	27R 1%
R3	3k3
R4,5,8	10k
R6	2k2
R7	1M0
RV1	1k0 cermet preset

CAPACITORS

C1,2	220n polyester
C3	10µF 16V radial electrolytic

SEMICONDUCTORS

D1,2	BAT42
LED 1-10	Rectangular green LEDs
IC1	LM3914
IC2	7805

MISCELLANEOUS

SK1,2	PL259 connector
SW1	DPDT toggle switch
SW2	SPST toggle switch

PCBs; Diecast box approx 87 x 33 x 27mm and plastic box approx 123 x 63 x 32mm; FX2691 toroidal core; small length of co-axial cable; nuts and bolts.

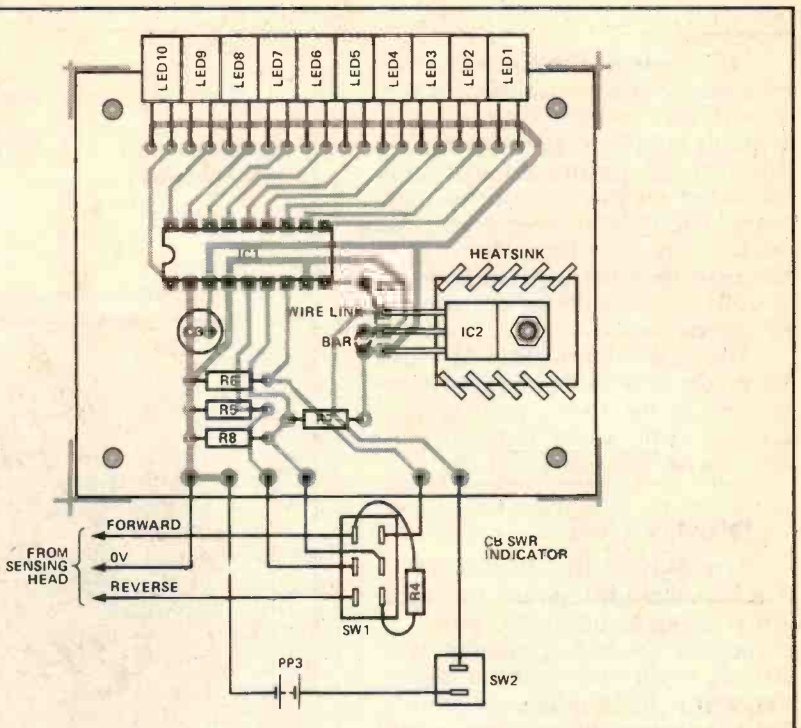


Fig.8 The component overlay for the display unit board.

switched to read power or SWR. In the power mode the internal voltage reference is used to drive the reference chain and if the specified components are used throughout this will give a full scale reading of 5W.

If a higher reading is required, a potential divider resistor should be added as shown in Fig.6.

When the display unit is switched to SWR, the reflected power is displayed as a proportion of the forward power. This gives a measurement of SWR which is largely independent of power. The only power dependence is at very low power when the efficiency of the sensing head is reduced.

Very high SWR readings are not of interest in adjusting a (hopefully) fairly efficient antenna, so the forward signal is potted down by R7, R4 and the resistance of the comparator divider chain on the IC which puts approximately 3:1 SWR at the sixth LED along.

The bargraph IC used can provide either a dot or bar display. The bar display looks better but if the unit is powered by a battery, bar mode will run down the battery much faster. It is possible to power the unit from the 12V CB power supply, in which case the bar display is definitely to be preferred. Otherwise a choice must be made between long battery life and the better looking display. A link is provided on the PCB to select the chosen mode.

The brightness of the display is determined by R6, the LED current being approximately ten times the current in R6.

When the CB rig is on receive, there is no forward signal to bias the reference input of the bargraph IC. In this condition, the entire row of LEDs could be switched on instead of being switched off as they should be. To prevent this, R6 provides about 25mV of bias in the absence of signal.

Construction

To achieve reasonable accuracy of measurement, the sensing head should be constructed neatly with minimum wire lengths (Fig.7). Long wires dangling around inside the equipment can cause stray coupling of the 27MHz RF with a consequent loss of directionality of the detection system. It is recommended that the specified case or a close equivalent is used.

Before any components are mounted on the PCB, the connectors should be mounted on the main body of the case and the board on the lid. When the board is temporarily mounted on the lid, the hole in the board under the preset pot (to permit calibration) should be drilled out to a size large enough to admit a trimming pool with an insulating sleeve slipped over the blade and the hole should be continued through the case. This will ensure accurate lining up of the holes when the time comes to adjust the unit with the lid closed.

The components should be mounted on the PCB, with R3 connected only at one end, ready to connect to the inner of one of the co-axial connectors. The toroid itself should be wound with 16 turns of fairly thin wire (about 0.25mm diameter). It should be slipped over a piece of coaxial cable already cut to length and stripped and tinned.

Remember that only one end of the braid should be grounded, to act as an electrostatic shield. If both ends are grounded the current transformer will pick up very little.

The leads of the toroidal current transformer and of R3 should be trimmed so there is enough length to permit the board to be connected and then mounted on the lid but not much extra. The output leads to the jack socket may be a little longer because they carry no RF but they should be dressed away from the RF connections.

The earth connections should be made to a solder tag mounted on one of the fixing bolts of the co-axial connectors and should also be as short as practical.

Display Unit

Assembly of the display unit (Fig.8) is straightforward but there are choices to be made. The choice of dot or bar display has already been mentioned and if the unit is to be powered from the CB power supply then a non-reversible connector should be selected and fitted to connect the supply. Just to be on the safe side, it would be a good idea to include a diode in series with the supply to prevent an unfortunate conflagration should it be connected the wrong way round!

If an internal battery is to be used to power the unit, then a cutout must be made in the PCB as shown in the photograph of the display unit.

If only dot display is to be used, then IC2, the 5V regulator need not have a heatsink fitted. Otherwise a small heatsink should be used.

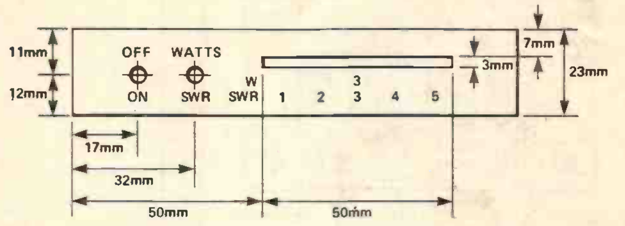
Facia

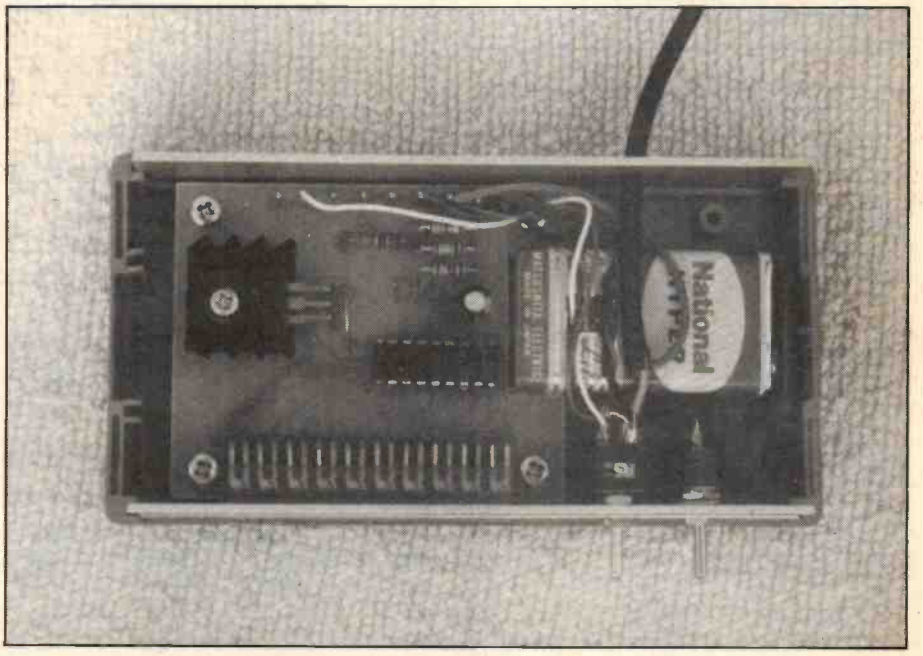
The difficult part is cutting the slot for the LEDs in the front panel (Fig.9). If the recommended case is used, the mounting holes in the PCB will line up with the bosses inside the case. The way to mark the slot is to mount the LEDs on the board in a straight line, then fit the front panel into the top of the box, and lay the PCB in the top, to which it will eventually be screwed. Line the mounting holes up with the bosses in the side to side axis, and slide the board forward until the LEDs touch the front panel.

After double checking that the board has not moved sideways, mark round the top and both sides of the line of LEDs. Remove the front panel and tidy up the marks with a scriber and rule, and mark the width of the slot as well.

These markings are on the inside of the case, so will not show. The best way to proceed is

Fig.9 The front panel layout.





to make a line of centre punchings along the middle of the slot, and then drill a row of small holes. Finally, use a rectangular needle file to join up the holes into a slot. Patience is needed at this point or the finish will be spoilt.

When the slot is accurate and the LEDs fit, holes can be drilled for the two subminiature switches.

One or two holes are required in the back panel as well. If battery power is to be used, the only hole needed is for the lead to the sensing head. If external power is to be used as well, the connector or flying lead also requires a hole.

The wiring up of the PCB to the switches is not difficult. Note that R7 is mounted diagonally across the back of the SWR/Power switch and that the cable to the sensing head is soldered directly to the switch. This should not be connected, however, until the sensing head is adjusted.

Adjustment

To adjust the sensing head as accurately as posible, a good quality 50R load and a DVM are needed. First of all mark one of the co-axial connectors *Transmitter* and the other *Antenna*. Connect up the transmitter and the dummy load. Plug the connecting lead into the output of the sensing head and connect 10k (or thereabouts) load resistors between the outputs and ground.

Connect the DVM across one or other of the load resistors and switch on the transmitter. Use a trimming tool insulated with a plastic sleeve to adjust RV1 through the hole in the case of the sensing head. If the DVM is connected to the reflected output, there should be a sharp dip in output at some point. If there is not, connect the DVM to the other output and try again. The unit is correctly adjusted when there is very little or no voltage on the reflected output.

Note which wire is the reflected output and connect it to the correct pole of the switch on the display unit. Remember to thread it through the hole in the back of the case first!

Operation

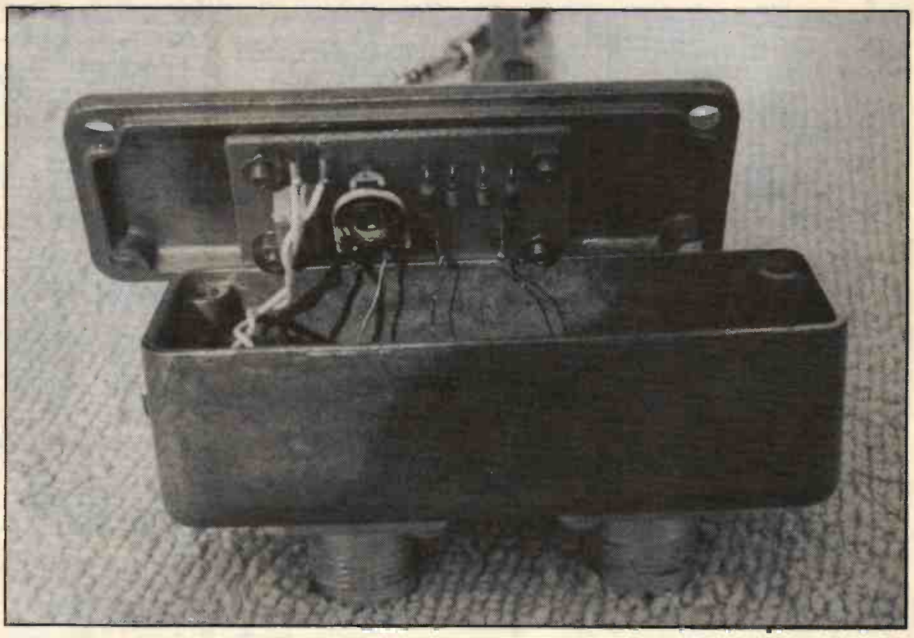
In operation, whether switched to power or SWR measurement, the display will only illuminate while transmitting. The power consumption for the rest of the time is low but is enough to run out a battery overnight if it is left switched on.

It is probably preferable to leave the unit switched to power reading for most of the time and only switch to SWR for the occasional check. If all is well then few or no LEDs will illuminate in the SWR mode so there will be nothing to see. This can be useful, for example, when using CB in a car.

The sensing head can be connected in the antenna lead out of sight while the display unit can be positioned on the dashboard where it can give a reassurance that the transmitter is working normally without the need to take the eyes off the road.

As I said at the start, the unit will work well on 2m with one component change. The toroid has too high an inductance for accurate operation on 2m — the phase shift of the current pickup is too large.

If a lower permeability core suitable for this frequency is used, it will work on 2m but not very well on CB. With the appropriate choice of core, the SWR indicator will work at HF or VHF, the only limitation being that the unit as it stands is designed for about 5W RF output maximum. **ETI**



BUYLINES

Most of the components are easily available from usual sources. The toroidal core and co-axial connectors are available from Cirkit.

The PCB is available from the ETI PCB service.

A complete kit of all parts (components, PCB, cases and connectors) for either CB or 2m operation is available for £24.50 including VAT from Cirkit, Park Lane, Broxborne, EN10 7NQ. Tel: (0992) 444111.

OPEN CHANNEL

The recent resignation of Sir George Jefferson from the top seat at British Telecom had been more or less expected, for personal reasons. Its timing, on the other hand, was not expected. His resignation came at the end of a long line of public criticisms about BT's operating record and may have appeared to have been brought about *by* those criticisms.

Analysed in detail, many of the criticisms aimed at BT have been shown as highly subjective and, because of this, unfair. For example, the largest criticism, (the London Business School's recent report on the cost of System X exchanges to the British telephone network and its users) noted that Britain would have been better off with foreign exchange equipment because no development costs would have been incurred.

Other criticisms in that report highlight the use of a procurement policy, a high development cost ($1.4 billion) and a failure to achieve exchange sales abroad.

The report was taken up by national newspapers in August (the silly season) and reported in terms of cost to the user, as a percentage of current call costs.

These criticisms are all based on factual evidence and of course the facts themselves cannot be disputed. However, the London Business School's interpretation of the facts is open to some criticism itself. First, the use of System X against other digital exchanges from foreign sources.

Buying British

In terms of development cost versus the cost of buying a foreign exchange, London Business School's estimate of $1.4 billion for System X may be correct (although it has been disputed) and if so does sound quite a lot compared with the only other two competitive foreign exchanges (the AT&T 5ESS at $0.75 billion and the Ericsson AXE at $0.5 billion).

However, what the report omits is that no other comparable exchange sufficiently advanced on a technical basis was available when BT decided upon the development route. So what should BT have done? Wait, in the hope that an acceptable digital exchange happened to arrive at an acceptable price, at an acceptable time?

Also what would be the consequences to the nation? Certainly, our telecommunications industry would be considerably weaker than it is today. Certainly, there would be a greater number of people on the dole queue. Don't we have enough troubles with the consequences of importing foreign technologies without doing the same with our telephone system?

At least now we have two companies within the UK (Plessey and GEC) with extremely good exchange design, development and manufacturing capabilities, to lead us into the 21st century and the next range of telephone equipment. We also have an exchange system which is at the forefront of current technology.

More Moans

As for the other criticisms in the London Business School's report: A procurement policy is apparently used by every other telecommunications organisation in the world. The high development cost is disputed by the exchange manufacturers and estimated at a lower figure of around $0.8 billion. Failure to export? It's certainly lower than what might have been expected but some sales *have* been made abroad. Well, they are subjective and other people may well put a different emphasis on the facts.

Don't get me wrong. I am always one of the first to criticise BT's operation but at least my criticisms are based on current problems, which BT can tackle. Criticisms like those in the London Business School's report are criticisms made in hindsight and I believe are subjective criticisms which can do no good.

BT hopefully has sufficient muscle to shrug them off and tackle the real problems of customer dissatisfaction.

In this respect, most other criticisms are individual ones, which can be remedied by BT on an individual basis. Problems with reaching the directory enquiries service (particularly in London) for example, have to be overcome one way or another directly by BT. Problems with new System X installations, though, are commissioning problems for which the suppliers must be criticised and not BT (the user in these cases).

Our telephone service is a good one. Don't let's forget that. It is also rapidly getting better. The rate at which the service improves can only be hampered by subjective, destructive criticism. Objective, constructive criticism should be our aim.

Keith Brindley

ONCE OVER

Pressure mats, window foils and passive infra-red detectors are all very well for sophisticated alarm systems but they are a perfect pain to install and only as effective as the control unit and siren or bell they're connected to.

What every good burglar really needs to set him running is the threat of a set of canine gnashers sinking into his backside.

This thought is not an original one and many insurance companies will give discounts on home contents policies if a dog is in residence.

The trouble with dogs, however, is that they are even more of a pain. They require feeding, exercising and to start with they require training and cleaning!

What a blessing for dog loathers everywhere is TK's Electronic Guard Dog kit. This clever but remarkably simple circuit provides on command a very reasonable imitation of a dog barking.

Almost all parts required for a complete dog are provided in the £21.95+VAT kit. All that is required is a case and (for the perfectionist) a couple of rotary pots and knobs.

The assembled Electronic Guard Dog is mains powered and triggered by a closing contact. It then gives a few 'barks' spaced at random intervals through the horn speaker. The pitch of the 'barks' can be varied from 'terrier to alsatian'!

The effect is remarkably realistic. In the same room the barks do sound a bit electronic but through a closed door or down a corridor it is genuinely difficult to tell that these barks are not going to be followed by bites!

The PCB is about 2 x 2½in in size and is crammed with three ICs, five transistors, seven diodes, 11 capacitors and 16 resistors, not to mention a terminal block and off-board jack socket, transformer and speaker.

The instructions provided are a little scrappy — they're all on one fading photocopied sheet — but they are clear and correct. The kit I was supplied with had all the parts present and correct (with one extra capacitor, in fact) and it worked perfectly first time.

The barks are formed from a voltage controlled oscillator feeding a simple amplifier which drives the horn speaker. The oscillator is gated by a random sequence generator formed from the usual exclusive-OR-feedback shift register clocked from a simple multivibrator giving a sequence about 15 clocks long. A monostable gates the multivibrator to provide a set length of the bark sequence.

Almost all the circuit is based on CMOS logic with only the amplifier based around the power transistors. A preset is provided to alter the frequency of the VCO (the pitch of the bark) and information is given on the instruction sheet to change the length of the bark sequence and interval between barks. Being a perfectionist I mounted two pots on the outside of the case for adjusting bark pitch and interval.

A random modulation of the bark frequency and even a low growl in between barks would make the dog imitation more realistic but I guess you can't be too fussy with a simple and cheap kit like this.

The biggest omission is a more versatile triggering mechanism. As it stands, the circuit requires two contacts to be connected to start the barks. However, few alarm triggering devices switch a relay. Most produce a high or low voltage which may well be unsuitable.

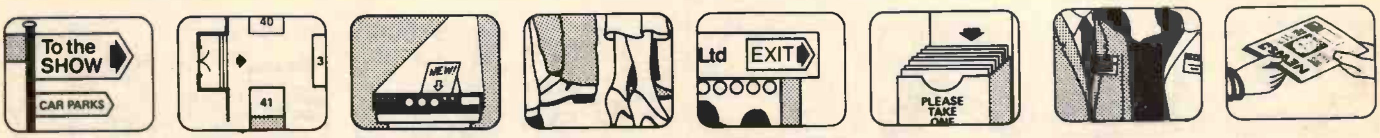
The obvious application for the Electronic Guard Dog is to connect it to your doorbell. This is covered in the instructions but will usually require a bridge rectifier and an opto-isolator. It would have been nice to see all this incorporated on the PCB and the components provided in the kit.

However, for £21.95 the Electronic Guard Dog is an entertaining product, the kit is simple and even instructive to build, and it could just prove to be worth its weight in doggy chocs the next time the nice gentleman in the mask and striped jersey comes visiting.

TK Electronics
13 Boston Road,
London,
W7 3SJ.
Tel: 01-579 9794

Martin Tame

THE HI-FI SHOW



Some psychologists regard hi-fi as a subject with distinct sexual overtones. Grown men lust after it. Some will give almost anything to obtain it and when they do they boast about it at great length to similarly obsessed friends. Glossy magazines print full-colour pictures of the latest models which are then passed around goggle-eyed initiates.

Meanwhile the wife (for it is almost always men who get stuck on hi-fi) stays at home and wonders if the marriage will survive this new passion.

These overtones are rarely as apparent as they were at the 1987 Hi-Fi Show, held on September 17-20th at the Heathrow Penta Hotel, London. While some manufacturers displayed their wares in large halls downstairs, the bulk of the show took place in hotel bedrooms on the first floor.

There, soft music (or in some cases very loud music) poured from discreetly open doors as hi-fi sirens competed to attract the thronging hordes of almost exclusively male visitors.

Carefully-groomed women sat at card tables beside closed doors, encouraging and placating the queues which grew steadily as the time of the next demonstration approached. Then the doors would open and the occupants of the crowded rooms would reel out, sweat soaked and visibly moved, to compare prices and vital statistics in furtive groups before stumbling off in search of further delights.

The Hi-Fi Show lacks some of the surface gloss of other major audio events but the clubby, almost conspiratorial atmosphere more than makes up for it. While the larger companies demonstrated in conditions much like those found at any trade show, some of the smaller outfits settled for cheerfully chaotic presentations in which personality counted for at least as much as the product. One-man companies gave one-man shows and luminaries like Tim de Paravicini of Esoteric Audio Research could be found holding court in tiny hotels rooms, playing favourite records and dispensing advice, opinion and reminiscence.

In this heady atmosphere it was difficult to decide what sounded good and what didn't. Some closed-door demonstrations were very good but most companies chose to audition their equipment in semi-open conditions where concentration was impossible.

This is an inevitable problem at any hi-fi show and the wonder is that some of the equipment sounded as good as it did. One or two of the smaller companies managed to overcome the limitations but I'm loathe to place too much weight on the subjective impressions gained in such an environment.

The watchwords at this year's show seemed to be vinyl, valve, class A, analogue and (just to be fair) digital. I was intrigued to see how many companies — even quite major ones — were using analogue record decks as a source rather than CD. Linn Sondeks were at least as much in evidence as Cambridge CD1s (the choice, I note, of quite a few of those who preferred CD) while elsewhere Pink Triangles, Revolvers and even more exotic rotating thingummies were to be found feeding top-flight systems.

Thorens was showing the newly-reintroduced TD-160 deck, now known as the TD-160S, while Voyd Turntables demonstrated a novel design which uses three electronically-controlled motors to ensure stability. It looks pretty unusual but not as unusual as the Crystal turntable from Oxford Acoustics which resembles a wooden sundial and is billed as the 'ultimate development of the vinyl analogue disc player'.

Record cartridges were on display but it often wasn't made clear which cartridge was being used for a particular demonstration. For this reason they made little impression on me, the only one I recall being the aptly-named design for use with the Revolver turntable. It's called The Bullet.

There was certainly no sign of a decline in the number of valve amplifiers. Beard, EAR and Conrad-Johnson were among those launching new valve products or updates of earlier ones while Luxman continued to push its valve-semiconductor hybrid amps which have a neat little window in the front panel to show off the glowing triodes.

Radford demonstrated the new Renaissance version of the much-lamented STA-25 amplifier but did so through Rogers loudspeakers, a great shame when one remembers that Radford was once better known for its loudspeakers than for amplifiers.

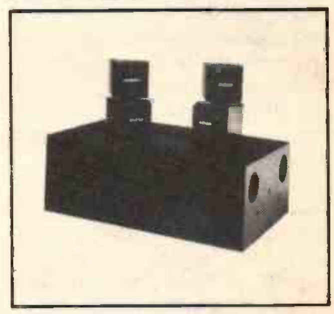
Class A was judged to be a good selling point by several manufacturers and not only for power amplifiers. Luxman was making much of its new class A preamplifier, an idea which might not sound so new to those who recall that most preamplifiers were effectively class A until the arrival of the operational amplifier in IC form. Musical Fidelity was content to employ class A operation only in its power amplifiers but added to the quality/mystique/price of the products by claiming the use of linear crystal oxygen-free copper cable for all internal wiring. Perhaps ordinary wire only operates in class B!

Digital was less heavily hyped than it might have been but there was still a lot of fuss being made about amplifiers with built-in ADC converters. There were also numerous new CD players on show but the most interesting for my money was the CD2 from Cambridge Audio. It boasts 16 bits and 16 times oversampling. Given the way the CD1 has established itself as a near standard the CD2 should be well worth watching.

Digital audio tape was much talked about but little seen. With Sony launching the first domestic DAT machine in the UK shortly after the show, one might have expected a few other manufacturers to take up the challenge and unveil their own models (most of them already have DAT products on sale in Japan or the US). In practice the only machines I saw were from Luxman and Kenwood, while Sansui showed a mock-up of one of its overseas products and admitted it wasn't sure when, if at all, it would be launched in the UK. The Luxman product will sell for around £1500 and is due for launch in November. Kenwood expects its DAT recorder to sell for under £1000 and spoke of launching it next spring.

The question of analogue versus digital in tape machines was also being raised by EAR, Altarus Records and Townshend International who have dubbed themselves the Analogue Allies. Their pamphlet argues that analogue tape bias frequency is directly equivalent to digital sampling rate, giving analogue a rate of around 120kHz compared to the 44.1kHz and 48kHz of CD and DAT. Furthermore they claim the quantisation levels obtained on analogue tape are equivalent to 22 or 23 bits compared with the 14 or 16 bits used in current digital recordings. On this basis they claim analogue is capable of far better results than digital. If you're interested, the pamphlet can be obtained from Department AA, PO Box 191, Sevenoaks, Kent TN13 3XX.

There were plenty of new loudspeakers but again the problem was deciding which sounded best in such an unhelpful environment. Of immediate visual appeal was the Bose Acoustimass system — a stereo loudspeaker set up which is so small as to be nearly invisible. It consists of a woofer box which lies on the floor and four tiny loudspeakers, each about as big as a couple of cigarette packets, which are supported in pairs on two metal poles. They certainly don't sound bad for the size.



In the automobile department the problems of size and appearance are receiving similar attention. Kef has decided that reasonable bass response cannot be achieved with the usual size of car loudspeakers and has chosento use larger bass drivers and place them in sealed boxes in the boot. The sound is fed out by means of large diameter flexible hoses to normal size loudspeaker grilles mounted on the rear parcel shelf. The middle and high frequencies are taken care of by separate drive units mounted directly through the parcel shelf in the normal way. I've no idea what they sound like in use and given the prices I'm unlikely to be fitting any in my car in the near future.

More in the 'why didn't I think of it first' category is a set of active loudspeakers from A&R. They are compact, produce about 15W

apiece and can operate from car batteries as well as the mains. A&R are marketing them as the ideal accompaniment to a picnic or beach party where they can be fed from a Walkman-style tape player.

Away from the purely hi-fi side of things the most widely trumpeted new product at the show was Philips' CD Video player. Similar machines have already been seen by the press and at trade shows but in theory at least this was the first public showing of the new system. It brings together the existing 8in and 12in laser disc formats and the audio compact disc and adds to them a new format — a 5in gold compact disc which can hold six minutes of video and stereo digital sound plus a further 20 minutes of stereo sound only. The Philips CDV 475 player handles all four types of disc.

I cannot finish without mentioning Yamaha's limited edition Centennial range. Yamaha has been going since 1887 and to celbrate has launched three products destined to strike fear into the stoutest heart and metal fatigue into the stoutest table.

Large, solid and very heavy they feature brushed silvery metal front panels, polished wooden side cheeks and enormous feet in a style I suspect is intended to be timeless but which will almost certainly date very quickly.

The power amplifier has almost all of its front panel area taken up with two huge moving coil meters while the preamplifier is grandly titled a digital control amplifier and features digital signal handling and a digital sound processor designed to add concert hall and other ambience to the music as required. The range is completed by a 16-bit, four times oversampled CD player which, like the preamp, is equipped will full remote control. I'm sure they sound great and are well worth an audition at home but please, please make sure the floorboards are up to it first!

Ian Pitt

PLAYBACK

It's always nice to receive a little feedback. Earlier this month the offices of ETI received the following letter on September's Playback from Mr. R. Mudhar of Southampton:

I agree wholeheartedly that, were it possible to replicate at my ears in my listening room the sounds I would perceive at my ideal listening position in the case of music which has an 'original sound' then one could go no further. Hi-fi will never achieve that.

This also leaves the question of the large majority of recorded music sold which has no 'original sound' but nevertheless has validity in its own right.

Testing Times

Rather than use instruments to find what is wrong with the signal, let us set ourselves an easier task. Assuming that for a signal to be listenable at all, there is more of what is right with it than what is wrong with it, let us look for some basic things contained in music.

Is there test gear which can:

- *print out the words of a song from the sound?*
- *tell Bach from Beethoven?*
- *tell from a song if it is sad, hopeful or happy?*
- *tell if the sax is in tune with the lead guitar?*
- *tell if anything is in tune at all?*

These are no arcane hi-fi subtleties. They are gross aspects vital to the perception of music. I take it as self-evident that to assess something that will pass beautiful music I must be able to perceive beauty and music.

To use test gear as a criterion of sound quality is like going to a concert with earplugs. Why do it?

Specs

If I tell you one amplifier has 0.01% THD and a frequency response flat to 2dB in the 20-20kHz range and another has a THD of 2% and a frequency response flat to 0.01% in the same range, can you honestly tell me which will sound better? To whom? With what music?

If the hi-fi mags printed reams of test statistics would you be able to advise your father-in-law with any chance of getting the best sound for the father-in-law, in his living room? Anybody who has been at any live meeting will have some idea of what perspective or depth might mean — if you can hear that someone is yelling far away and on the left and someone else is close by on the right you have perspective and depth.

That is a lot better than being a degree course away from knowing what a frequency reponse of ± 0.01dB 20Hz to 20kHz at 0.01% THD means. Criticism can be levelled at the hi-fi mags for the high price of the gear they typically review but I respect someone who has the courage to say that they like the sound of their kind of music via that piece of kit much more than someone who presents a mass of figures uninterpretable to 95% of their readership.

Those tests that have been undertaken with a decent degree of open-mindedness have used instrumentation of a precision that befits university and research facilities, not maintenance gear. I refer Mr Armstrong to the work by Jean Hiraga on 'Pickup Musicality' and 'Amplifier Musicality' in the April and March 1977 issues of Hi-fi News & Record Review which attempt to break the usual insanity of averaging out all distortion. I am happy to say that Mr Hiraga took careful measurements and attempted to correlate these with subjective findings rather than hiding behind a barrage of test results.

Boring Worlds

The bottom line is that until we live in a boring world where we all listen to the same music with the same ears in the same way then a person's reaction to music or degredation of the same will inevitably fail the axiomatic requirement for something to be scientifically observable — the same stimulus to appear the same to all observers.

We listen to music in a subjective manner. The diversity of musical tastes shows that. It is clear that the annoyance of interference to the music is entirely subjective. There never will be an objective assessment of the interference to the music as perceived and surely it is this interference as perceived we are trying to reduce. Is not hi-fi there to enhance the quality of life of the human listener, rather than a lab full of test equipment?

Science has given us much of value, but let us not stand so much in awe of it that we fear that side of us that science cannot know.

Well...

Mr. Mudhar has made a number of valid and interesting points but he does seem to have read a different column from the one I wrote. My severest critic says that (just for once) I then stated my case quite clearly — in the third and fourth paragraphs.

Of course listening pleasure is subjective, as I implied at the time, but we are talking *hi-fi* here, which means *'high fidelity'* — faithful reproduction. The implied purpose of hi-fi is to reproduce the sound of the music played at its source (see that September Playback again).

I happen to enjoy live music and well-played studio recordings. As no hi-fi is perfect, I prefer to have some choice as to what distortion and how much I have to suffer so, yes, THD and frequency response measurements are useful to me in choosing gear for myself and others. They are the least arcane factors quoted by some hi-fi reviewers.

What I object to is the vague confusion of good reproduction and 'musicality'. They are two different things. The use of the term 'musicality' implies that the sound reproduction equipment colours the sound in such a way as to make it more pleasing to the listener. This may be fair enough but it is not the aim of hi-fi. What's more, subjective comments are not useful as an assessment of sound quality because one person's pleasant colouration is another's dreadful noise.

Musical Money

On the other hand, harmonic distortion and frequency response ripple are objective measurements, from which the individual can estimate the suitability of equipment for his own needs. But when instead of this it is implied that a piece of cable, or whatever, is 'musical' and therefore worth triple the price or worse, I smell the presence of bewildered punters who won't trust their ears and are therefore mugs for large sums of money.

Their money would be better spent going to a few concerts to find out what they really do like.

I would like to read Jean Hiraga's work, as he seems to have done exactly what I recommended — carried out measurements to determine the physical basis for a subjective phenomenon. But why are his conclusions 'careful measurements' and mine 'a barrage of test results'?

Another case of woolly words being easier to sell than facts?

Andrew Armstrong

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E8408-4	Infrared Alarm Receiver	F
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E8511-3	Specdrum	L
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E8604-3	Matchbox Amp Bridging Version	C
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E8606-2	Midi-CV Converter PSU	D
E8606-3	Troglograph	F
E8606-4	80m Receiver	H
E8606-5	Sound Sampler	R
E8607-1	Directlon	E
E8607-2	Upgradeable Amp, MC stage (Stereo)	G
E8607-3	BBC Motor Controller	F
E8608-1	Digital Panel Meter	G
E8608-2	Upgradeable Amp, MM stage (mono)	H
E8609-1	Mains Conditioner	E
E8609-2	Experimental preamp	F
E8609-3	Upgradeable amp, Tone board (mono)	H

E8609-4	Upgradeable amp, Output board (mono)	F
E8610-1	Audio Analyser Filter Board	L
E8610-2	Audio Analyser Display Driver	K
E8610-3	Audio Analyser Display	H
E8610-4	Audio Analyser Power Supply	F
E8611-1	Audio Switcher (2 bds)	H
E8611-2	PLL Frequency meter (4 bds)	Q
E8611-3	Upgradeable Amp PSU	J
E8611-4	Call meter, main bd.	O
E8611-5	Call meter, interface bd	N
E8612-1	Bongo Box	J
E8612-2	Biofeedback monitor (Free PCB)	E
E8701-1	RGB Converter	F
E8701-2	Mains Controller	D
E8701-3	Flanger	H
E8701-4	Audio Selector main board	M
E8701-5	Audio Selector PSU	H
E8701-6	Tacho-Dwell	F
E8702-1	Ratemeter main board	K
E8702-2	Ratemeter ranging board	F
E8702-3	Photo Process Controller (3bds)	O
E8702-4	LEDline display board (2 off)	K
E8702-5	LEDline PSU and controller (2 bds)	G
E8703-1	Capacitometer	F
E8703-2	Geiger Counter	L
E8703-3	Credit Card Casino	E
E8704-1	BBC micro MIDI interface	L
E8704-2	ETIFaker patch box	H
E8704-3	24Hr. Sundial	E
E8705-3	MIDI Keyboard keyswitch boards (3 boards)	W
E8705-4	Batlite	C
E8705-5	Budget Power Meter	E
E8706-1	Hi-fi Power Meter	N
E8706-2	MIDI Keyboard CPU	U
E8706-3	MIDI Keyboard Front Panel	O
E8706-4	Flame Simulator	G
E8707-1	MIDI Keyboard PSU	H
E8707-2	Telephone Alarm	J
E8707-3	Nuclear Strategy Simulator	J
E8708-1	Remindalite	F
E8708-2	Rear Wiper Alarm	G
E8708-3	Rev Counter	F
E8708-4	Car alarm	F
E8708-5	Knight Raider	J
E8709-1	Boiler Controller	G
E8709-2	Amstrad Sampler (2 bds)	P
E8709-3	Portable PA	G
E8709-4	EEG Monitor (2 bds)	L
E8710-1	Concept CPU board	N
E8710-2	Concept Power board	K
E8710-3	Concept display board	G
E8710-4	Hyper-Fuzz	F
E8710-5	Big Digits digit board	N
E8710-6	Big Digits minute board	F
E8710-7	Big Digits battery board	G
E8711-1	Quiz Controller	E
E8711-2	256K Printer Buffer	N
E8712-1	Heating Management System	O
E8712-2	SWR Meter	H
E8712-3	Dream Machine (free PCB)	D

OOPS!

FM Stereo Tuner (February-April 1987)
In the parts list on page 49 of the February issue, C2 and C3 are listed as 270n types. This line should refer to C2 and C23 and the value should be 470n. In Fig. 7 the un-labelled PCB pad in the top right-hand corner is the +15V input from the power supply. In Fig. 1 in the April issue there is an un-labelled arrow leading from the top of the diagram. It should be marked CONTROL VOLTAGE OUTPUT TO MUTING CIRCUIT. The arrow to the right of the un-labelled one is marked '+5V IN' and should read '+15V IN'. In Fig. 6 in the April issue, C63 and C64 should be shown as 330p, not 3300p. On page 36 of the April issue, in the first paragraph, the reference to R62 should read R64.

Flat Alarm (June 1987)
In the circuit diagram Q2 is shown as an NPN transistor. It should be a PNP device as given in the parts list. IC4 is given in Fig. 2 as a 74LS260 and C5 as 470n. They should be 74LS132 and 4µ7 as in the parts list. R13 is incorrectly given as 280R in the parts list instead of 270R.

Nuclear Strategy Simulator (July 1987)
The bridge rectifier (BR1) on the overlay diagram has no polarity markings. It should be positioned with the positive at bottom left, connected to the track which connects to IC8 IN and C4 positive.

Telephone Alarm (July 1987)
In the component overlay (Fig. 2) ICl and IC2 should be swapped. In addition the capacitor to the right of ICl,2 is C1 and the inductor between them is L1. The unmarked resistor to the left of L1 should be a wire link.

Kappellmeisters (July 1987)
The position of the speaker port in the front panel was omitted from Fig.2. This should be a 7¼x4½in ellipse centred across the panel with its top edge 2½in below the panel top.

Knight Raider (August 1987)
In Fig.1(a) pins 4 and 5 of ICl are swapped. IC2-3 show the correct pin-out.

Car Alarm (August 1987)
In Fig. 1 Q7 is not numbered and its emitter is shown unconnected. This connects to earth. The transistors in the parts list went a little awry. Q2-6 are BC237 and Q7 is a TIP31.

Boiler Controller (September 1987)
In Fig. 2 (a) the primary of T2 is shown connected to Earth. This should be neutral. In Fig. 2(b) one of the bridge rectifier diodes, D6-9, is shown the wrong way around. This is correctly shown in Fig. 5.

ETI Concept (October 1987)
The Power Board parts list wrongly lists R6 as 270R. This should be 270k. Also, note that the power board's 0V rail must *not* be connected to Earth or the 0V rail of the CPU board.

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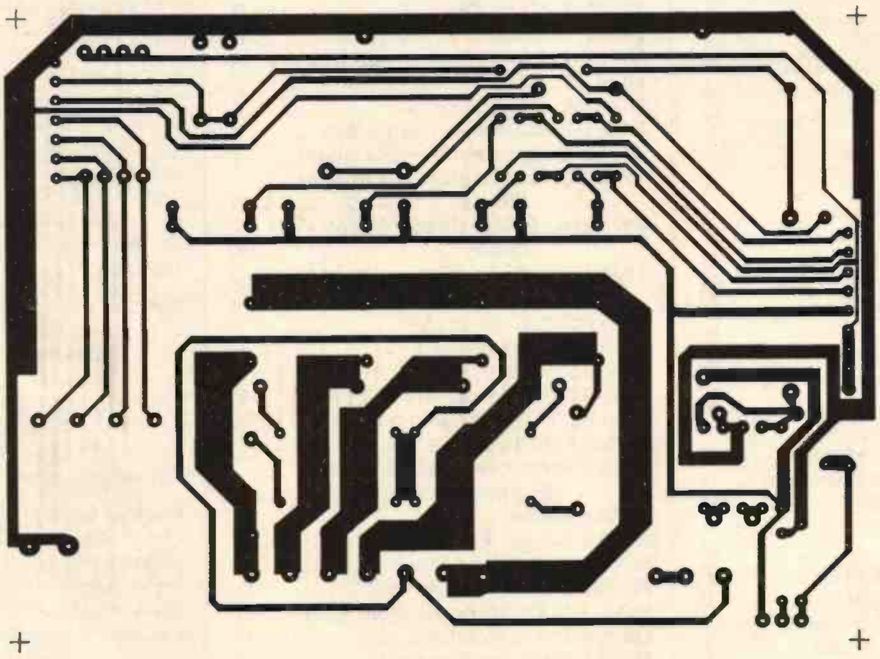

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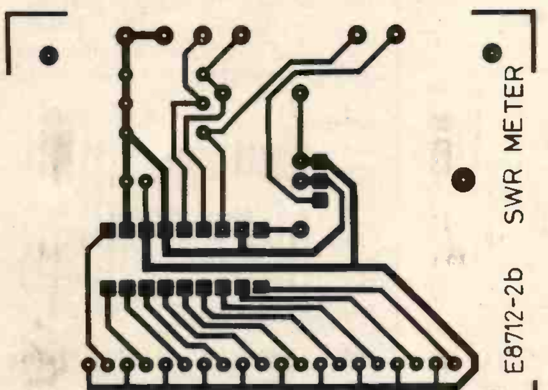
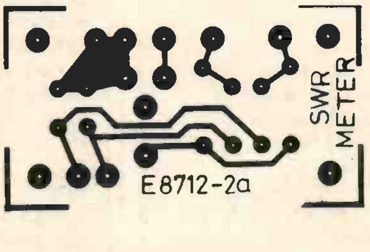
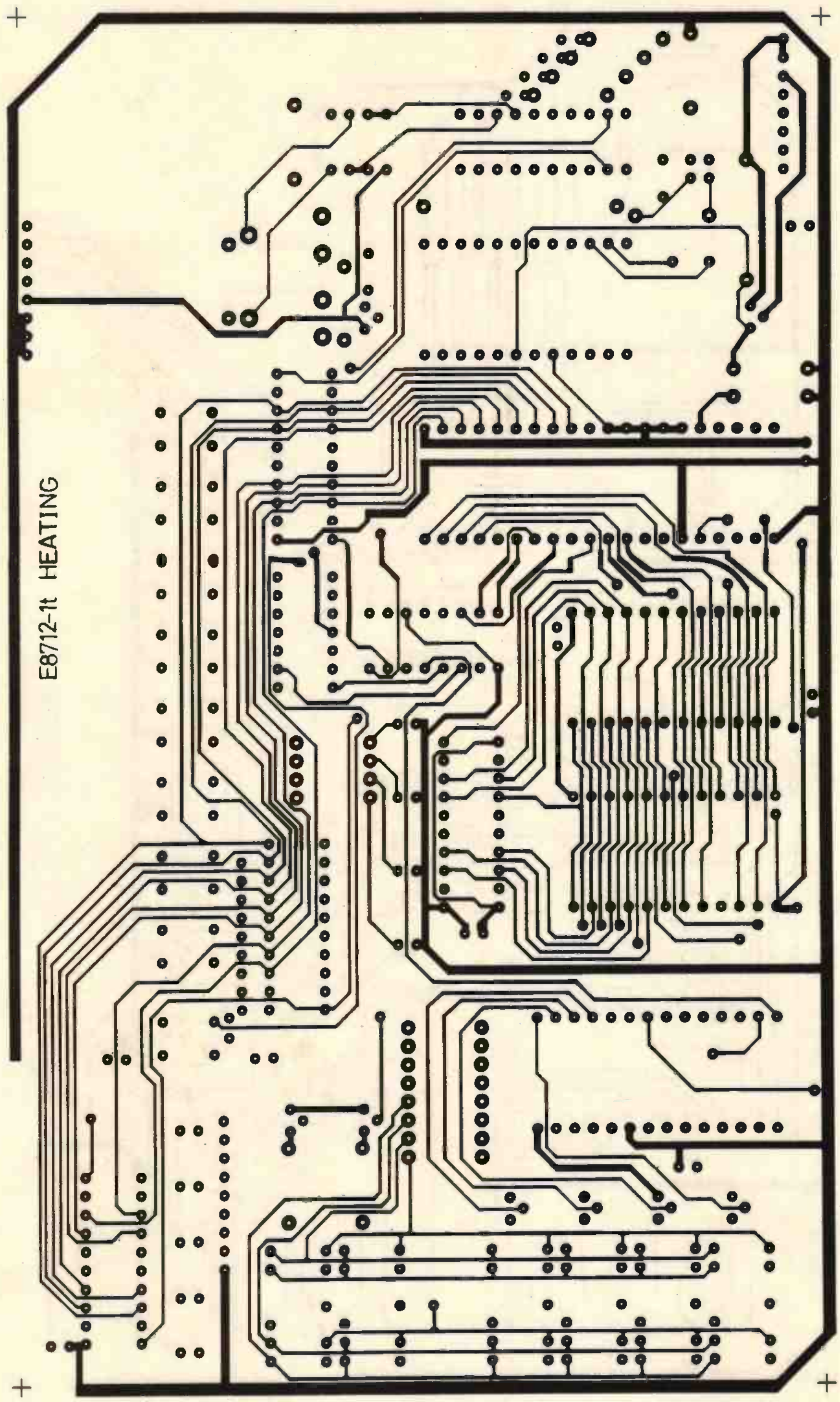


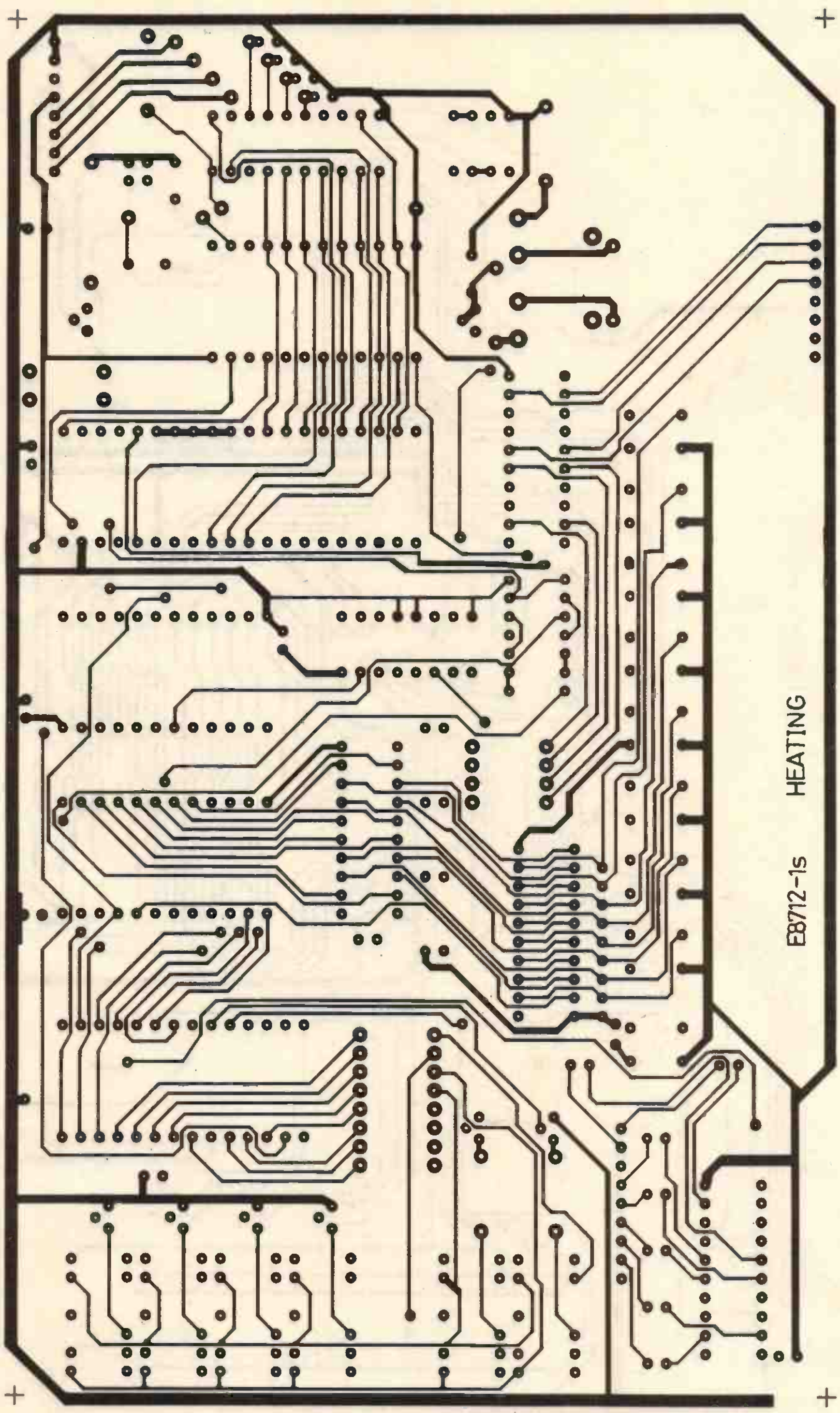
The SWR meter display board



The SWR meter sensor board



The Heating Management System main board topside foil



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