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ELECTRONICS

SCIENCE & TECHNOLOGY

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STEREO 30W HI-FI AMP

PE HI-STAB

LAB GRADE BENCH PSU

PROMENADER PLAY BACK

DESIGN — POWER SUPPLIES

CIRCUIT IDEAS FOR LOW DROP OUT PSUs

COMPUTING — BBC ADD-ON

A SLOWER RUNNING BEEB FOR PROGRAMMERS

TECHNOLOGY — LIQUID CRYSTALS

THE DISPLAY TECHNOLOGY OF THE FUTURE

EXPERIMENTATION — ULTRASONIC RANGING

A PRACTICAL ELECTRONIC RULER

PLUS:
- ★ SPACEWATCH
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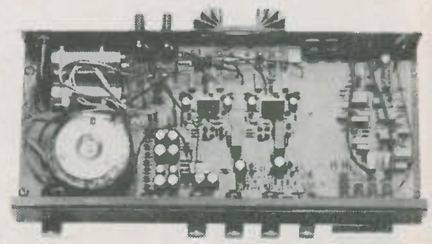
- ★ INDUSTRY NEWS
- ★ CIRCUIT IDEAS

RED BOX REVIEW

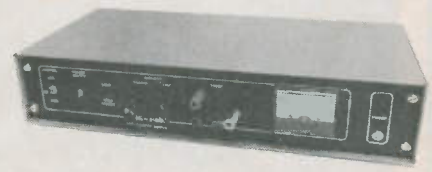
THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

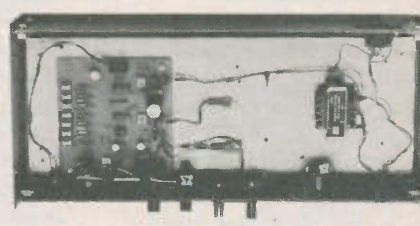
PRACTICAL ELECTRONICS FEBRUARY 1987

CONSTRUCTIONAL PROJECTS



SPECIAL FEATURES





REGULAR FEATURES

THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS

WHAT'S NEW . . .

CATALOGUE CASEBOOK

During the last month we have received the following catalogues:

The Enclosures Catalogue, Winter 1986/7 from West Hyde, costs £2 which can be recovered using the discount vouchers. 104 pages dealing with a large range of enclosures, project boxes and equipment housing. Details from: **West Hyde Developments Ltd.,** 9–10 Park Street, Industrial Estate, Aylesbury, Bucks HP20 1ET.

A new series on **Varistors, Thermistors and Sensors** from **Mullard.**

The ECIF handbook lists details of its member companies and components they supply costs £3. Details from: **ECIF,** 7–8 Saville Row, London W1X 1AF.

The **STC Multicomponents Catalogue** is a trade price list of components. Details from: **STC Components,** Edinburgh Way, Harlow, Essex.

A booklet from Castle Associates detailing their range of **noise and vibration measuring instruments.** Details from **Castle Associates Ltd.,** Salter Road, Scarborough YO11 3UZ.

An 80-page brochure from Hitachi summarising details of the **latest high technology products and technologies.** Details from: **Hitachi Electronic Components Ltd.,** 21 Upton Road, Watford, Herts.

A new 16-page **connector catalogue** from Bulgin covers DIN 41612 and others. Details from: **A.F. Bulgin & Company PLC,** Bypass Road, Barking, Essex IG11 0AZ.

A free booklet from De Beers concerning the **machining of ceramics.** Details from: De Beers Industrial Diamond Division, Charters, Sunninghill, Ascot, Berks.

The 'Bigger Than Ever' **Maplins Buyer's Guide To Electronic Components** is now available through many good high street newsagents or direct from **Maplin.** Mail order.

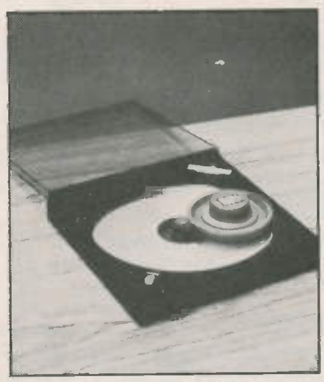
Crofton Electronics **monitors, cables and connector catalogue** available from **Crofton Electronics.**

Loc-kit

A new electronic lock kit is the latest addition to TK Electronics' range of high quality kits. Supplied with high quality p.c.b., all components including piezo sounder and connectors, the kit – XK121 in the new TK catalogue – is priced at £15.95. A set of keyboard switches is available at £4.00.

Features of the lock kit include: possible 5,000 4-digit combinations, open sequence easily changed, alarm sounder after three or nine incorrect entries, choice of keyboard, output driver to operate most relays or the TK lock mechanism which sells at £16.50.

The kit which operates from a 9V to 15V supply will find many applications in the garage, home or workshop.



CD Cleaner

There is much discussion within the CD industry about the value of CD cleaners as many would say that they are totally unnecessary. However, Bibs new style radial CD cleaner is playing an important role in the launch of the K-Tel CD range launch. They are offering one free (normally worth £9.95) with two or more CDs bought from their new CD range.

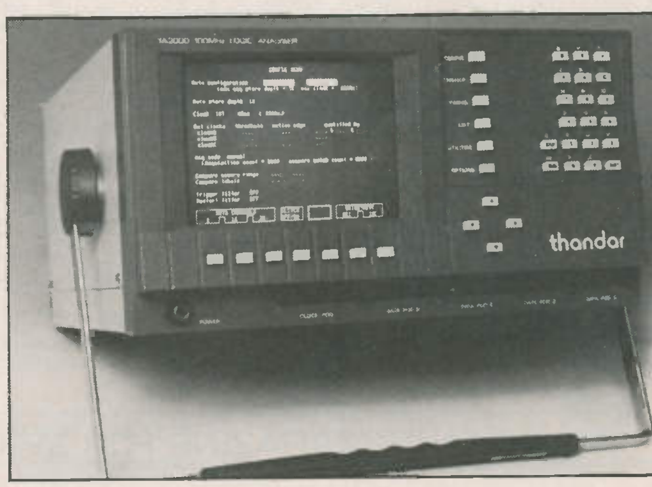
IR Head Phones

A good idea from Kewmode is their new 'spatial sound' IR headphones. Simply plug in a small transmitter to your TV or hi-fi phono socket and you can listen to the sound up to 40 feet away. The idea is similar to the PE IR Communicator and offers a single audio channel. The headphones convert the single channel into pseudo-stereo, thus the 'spatial sound' description. We haven't actually tried them yet, but suspect that they are largely directional and therefore might cause problems if you want to walk and listen.

Portable Analyser

A new logic analyser from Thandar, the TA2000 can capture data across 32 channels at 25MHz and up to 100MHz for eight channels. Other features include multi-level triggering, 5ns glitch capture and glitch triggering, high impedance input pods with software controlled variable thresholds, and three external clocks.

IEEE and Centronics interface are standard and disassemblers for 8-bit and 16-bit microprocessors are optional.



Low Cost Programming

A new programming system from GP Industrial Electronics can be connected to an IBM or clone to provide a range of programming functions. It can be used to program bipolar PROMS, single chip microprocessors and PALs. The system hardware, the XU620, costs £395 and the software, XUDRIVE, costs £245.

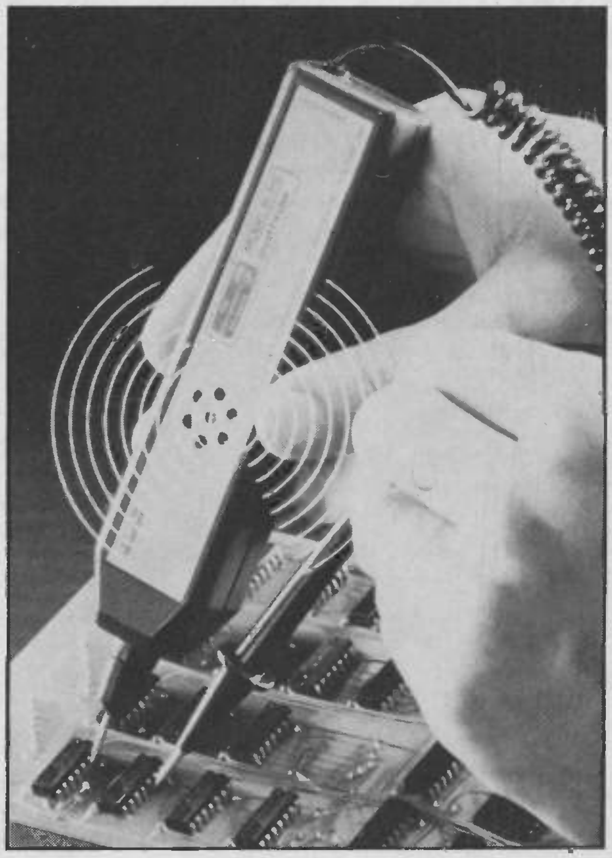
Cirkit's Circuits

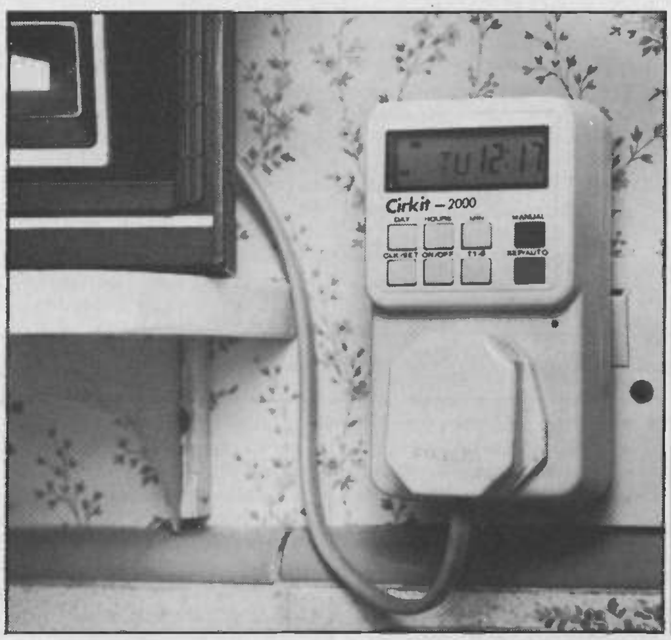
A plug in timer which gives multi-programmable switching for any electrical appliance up to 3KW is now available from Cirkit. Called the Cirkit 2000, the device allows any appliance to be switched on or off up to six times a day. In the event of power failure, the battery back-up circuit included will retain the program. However, it cannot, obviously, power any appliance should it be needed on during this time.

Beeb Add-Ons

It is now possible to share a single Winchester disc drive between four BBC micros using the new multiplexer from Technomatic. This is the latest addition to their extensive range of computer hardware products. The units are available in two versions, the dual unit for two micros and the quad unit for four micros.

All computers used in the system have to be fitted with the ADFS but do not require any additional software or hardware modifications. The system allows the user to access common software and transfer data between computers.





Psion Book

There is now a useful book for Psion Organiser owners. The Psion organiser is a very popular hand-held 'computer' and until now has lacked the backup of an independently written guide.

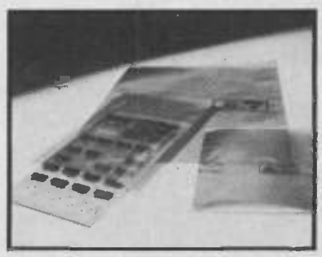
'Using and Programming the Psion Organiser II' is written by Mike Shaw and costs £9.95 and is available from good book shops and Psion stockists.

Short Finder

A battery operated short finder from OK Industries is now available for £32.48 plus VAT. It has two audible thresholds for optimum performance on p.c.b.s with different trace width and lengths. It is said to eliminate false readings and errors due to leakage currents or capacitor resonance.

Matching Minis

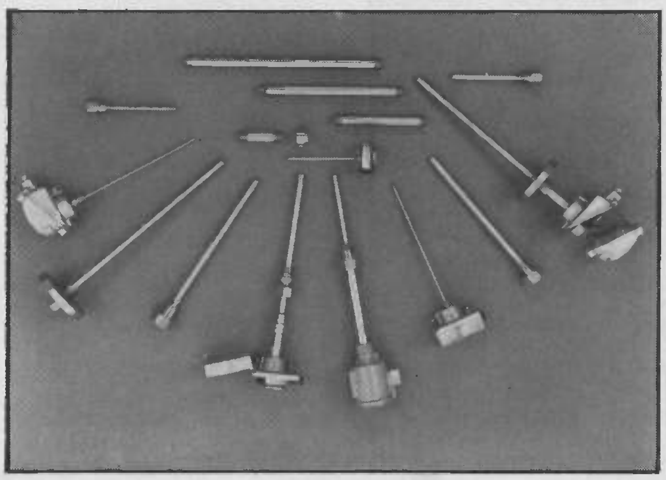
A high quality line isolation for interfacing BT lines to subscriber apparatus is now available from Kenton Research. It meets various BS standards and the BT Technical Guide 26. Vacuum-resin cast, the 01110 is p.c.b. mounted and utilises a standard 0.1 inch pitch.



P840 Thermowells

The P840 temperature transmitter, a field mounted, two wire device, for the measurement of low level d.c. signals, manufactured by Kent Industrial Measurements Limited, a Brown Boveri Kent company, is now offered with a complete range of thermowells and accessories.

The thermowells, both 12mm OD and 16mm OD, are available in Inconel 600, as well as 316 stainless steel, with a selection of standard process connections, both screwed and flanged. Alternative screwed and flanged process connections may be provided on application.



Static Shield

A range of transparent metallised static shielding bags for storing or transporting static-sensitive p.c.b.s and assemblies is now available from OK Industries. Known as MAG bags they are of multi layer construction made from an aluminised layer coated with polyester and polyethylene.

Also from OK Industries is a new desoldering iron which is claimed to combine the ease and portability of a hand held manual desolderer with the performance of an industrial desoldering station.

WHAT'S HAPPENING

More on Microwave technology ...

FIRM CONTACT

Further details of the products, services and companies mentioned in the News pages of Practical Electronics may be obtained from the following sources:

Tektronix UK Ltd., Fourth Avenue, Globe Park, Marlow, Bucks SL7 1YD.

TK Electronics, 11 Boston Road, London W7 2SJ.

Technomatic Ltd., 17 Burnley Road, London NW10 1ED.

Cirkit Distribution, Park Lane, Broxbourne, Herts EN10 7NQ.

Bib Audio/Video Products Ltd., Kelsey House, Wood Lane End, Hemel Hempstead, Herts HP2 4RQ.

OK Industries UK Ltd., Barton Farm Industrial Estate, Chickenhall Lane, Eastleigh, Hants SO5 5RR.

Kewmode Limited, Unit C, Faircharm Ind. Estate, Evelyn Drive, Leicester LE3 2BU.

GP Industrial Electronics Ltd., Unit E, Huxley Close, Newham Industrial Estate, Plymouth PL7 4JN.

Thandar Electronics Ltd., London Road, St. Ives, Huntingdon, Cambridgeshire PE17 4HJ.

Kuma Computers Ltd., 12 Horseshoe Park, Pangbourne, Berks RG8 7JW.

Kenton Research Ltd., Electronics Components and Equipment, Unit 16, Europa Trading Estate, Erith, Kent DA8 1QL.

Maplin Electronic Supplies Ltd., PO Box 3, Rayleigh, Essex SS6 8LR.

De Beers Industrial Diamond Division Ltd., Charters, Sunninghill, Ascot, Berkshire SL5 9PX.

A.F. Bulgin & Company Plc, Bypass Road, Barking, Essex IG11 0AZ.

Hitachi Electronic Components (UK) Ltd., 21 Upton Road, Watford, Hertfordshire WD1 7TP.

Castle Associates Limited, Salter Road, Scarborough, Yorkshire YO11 3UZ.

ECIF, 7/8 Saville Row, London W1X 1AF.

Mullard Limited, Mullard House, Torrington Place, London WC1E 7HD.

Key Communications Limited, 30 Upper High Street, Thame, Oxon OX9 3EZ.

Norbain Technology Ltd., Norbain House, Boulton Road, Reading, Berkshire RG2 0LT.

Rapid Recall Limited, Rapid House, Denmark Street, High Wycombe, Buckinghamshire HP11 2ER.

Microwave tomorrow

British Telecoms have now entered the microwave network business with a contract worth £1.5m to design, integrate, and supply radio terminals to be used in a network linking British Petroleum's (BP) new Southern North Sea gas platforms with the mainland.

BT will supply microwave radio terminal equipment for operation at 1.5 – 1.7GHz including aerials, feeders, transmitters, receivers, multiplexors, supervisory equipment and ancillary gear for voice frequency telegraphy. It will be built and tested in BT's workshops in Islington, London, and then delivered to BP's fabrication site at Dimlington ready for erection there and offshore.

BT, of course, has plenty of experience in the microwave business – microwaves already form a large part of its trunk system and BT is continually developing and improving microwave technology. Next year they plan to start engineering trials of new modulation equipment which could increase capacity of its digital microwave radio network by up to a third. The new equipment operates in the lower 6GHz frequency band and uses techniques known as 64 QAM – quadrature amplitude modulation. 64 QAM is the latest method of making more efficient use of the radio spectrum and involves modulating the phase and the amplitude of the carrier. This enables the existing internationally recommended frequency channel plan to be re-utilised to produce a band utilisation somewhat better than the 1800 channel analogue system currently used in the band.

BT has a finger in most telecommunications pies including optical communications. Recently they successfully demonstrated the world's first all-optical regenerator which was developed by two engineers at BT's research labs at Martlesham Heath. Although still in the experimental

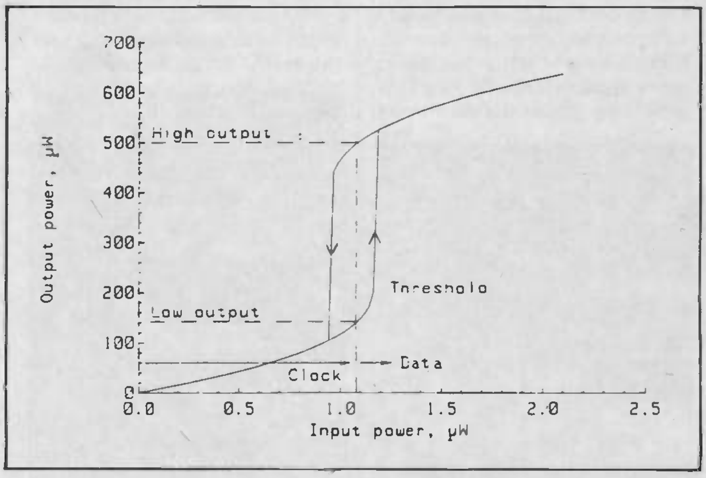


Fig.1. *Bistable amplifier chracteristic (theoretical).*

OR-what?

Once again, conflicting interests have prevented a world wide accepted standard becoming reality. Further to last month's report on Inter/active CD, we can now confirm that the logical file structure for CD ROM as drawn up by the High Sierra group is indeed different, albeit slightly, to that outlined in the Philips Green Book. The draft standard may become officially accepted by the ECMA (European Computer Manufacturers Association) and the ISO (International Standards Organisation).

Furthermore, to add even more potential confusion, at a recent meeting of the High Sierra Group an IBM representative suggested that the standard should not be referred to as CD ROM but OROM (Optical Read Only Memory). The reason for this suggestion was, apparently, that since the standard for CD was based upon the Philips Green Book which was only available to licensees, an international standard should not refer to a non-public domain product.

If this suggestion was accepted, things would be even more complicated as OROM generally refers to only 5¼ inch read only optical drives. Fortunately, however, it is unlikely that, in practice, even IBM will be able to change the name as it is already widely accepted.

WHAT'S TO COME

and more on the future of CD ...

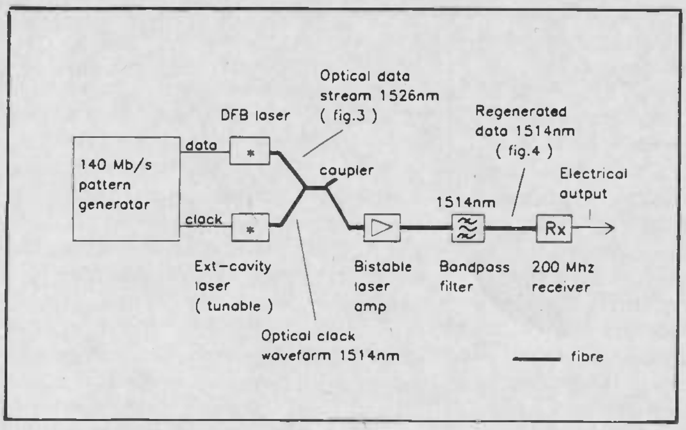


Fig.2. *Experimental all-optical regenerator*

stage the regenerator is planned for use in long distance optical links and will also be produced commercially by BT&D Technology, the optoelectronics company jointly owned by BT and Du Pont.

The all-optical regenerator functions as a decision gate which retimes and restores the levels of an optical data stream with no intermediate electronic stages.

It is based on the principle that a Fabry-Perot semiconductor laser has nonlinear output-power/input-power characteristics because its effective refractive index varies with optical power level. At some wavelengths this nonlinearity leads to bistability (Fig. 1).

To form a regenerator, an optical clock waveform consisting of a train of pulses with peak power just below the bistable threshold is combined with the data stream and coupled into the amplifier. When the data is low, a slightly amplified clock pulse appears at the output. When the data is high, the additional power is sufficient to exceed the threshold and the output jumps to a higher level, which is insensitive to the data power, and reverts to low only at the end of the clock pulse. The output is the regenerated data in return-to-zero form, retimed by the clock.

The output is at the same wavelength as the clock. However, the input data can be separated by multiples of the amplifier node spacing which in turn is determined by the length of the laser cavity.

The amplifier in the experimental system (Fig. 2) was a double-channel planar buried-heterostructure laser fabricated at British Telecom's research laboratories with facet reflectivity reduced to 3%. The wavelength and mean power of the clock waveform were set to 1514nm and 6μW in the amplifier input fibre, just below the bistable threshold. Small clock pulses appeared at the output.

Data input was provided from a distributed feed-back (DFB) laser. As continuous power from the DFB laser was gradually increased, a threshold was reached at which the output pulses abruptly jumped to a higher level.

When the DFB laser was modulated with a 140Mbit/s, return-to-zero pulse pattern, producing an optical data stream at 1526nm (Fig. 3), the regenerated pattern appeared at 1514nm with a mean power in the output fibre of 20uW (Fig. 4). Error rates of three in 100 million were obtained with a 2^{10}-1 bit non-return-to-zero pseudo-random data stream of mean power 3uW.

NEWS ...

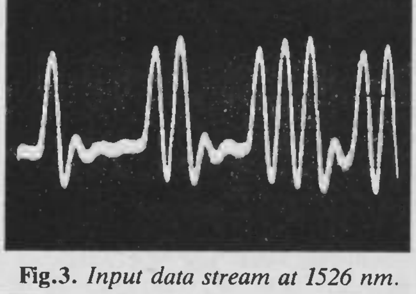


Fig.3. *Input data stream at 1526 nm.*

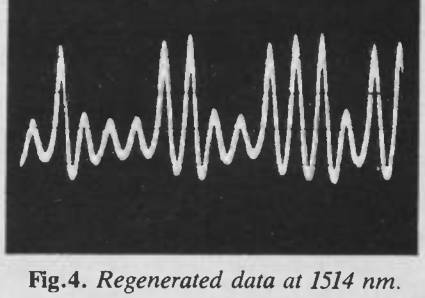


Fig.4. *Regenerated data at 1514 nm.*

COUNTDOWN

If you are organising any electrical, computing, electronic, radio or scientific event, big or small, drop us a line. We shall be glad to include it here. Address details to COUNTDOWN, Practical Electronics, 16 Garway Road, Bayswater, London W2 4NH.

PLEASE NOTE: Some of the exhibitions and events mentioned here are trade only or may be restricted to certain visitors. Also please check dates, times and any other relevant details with the organisers before setting out as we cannot guarantee the accuracy of the information presented here.

British Electronics Week '87, April 28–30, Olympia (incorporating All Electronics/ECIF show, Automatic Test Equipment, Circuit Technology, Electronic Product Design, Fibre Optics and Satellite Communications), (0799) 26699.

British Manufacturing Technology Week, June 2–5, Olympia (incorporating CIM), 01-891 3426.

Oman Office Equipment and Computer Show, March 22–26, Muscat, 01-486, 3741.

CHIP COUNT

Over the last month we have received details of the following:

The SCN8052, 8-bit microcontroller from Mullard based upon the popular 8051 circuit but with on-chip memory. Also from Mullard is the 8X401 8-bit controller using ECL technology, the PLS168 and PLS179 field programmable logic sequencers and a range of pyroelectric IR detectors designated RPWseries.

M2064 logic cell array from Monolithic memories combines user programmability with the density of VLSI. Available from Rapid Silicon.

Two high speed FIFOs from Rapid, the C67L401D and C67L402D are 'fall through'. FIFO memories organised 64 words by 4 bits and 64 words by 5 bits. Also from Rapid the the IMS G175P-20 INMOS device which is a low-cost colour look up table.

A new range of High Voltage Power MOSFETs designated the IXTP, H, M series, designed for high voltage switching and offering low on resistance, from Norbain Technologies.

THE LEADING EDGE

REPORT BY BARRY FOX

POLAROID now has the instant picture photography market to itself, after using its master patents on the basic technology to push out Kodak. This is good news for the UK. Polaroid re-invests 10% of its sales income in research and development at its laboratories in Cambridge, Mass. The result is a new camera called 'Image' now being manufactured in the Vale of Leven, Scotland, where Polaroid employs 1200 people in the largest camera factory in Western Europe and the only one in the UK. By contrast Kodak is cutting back drastically on its British operation – even colour film is now processed on the Continent. The Vale of Leven factory also subcontracts production of keyboards for the IBM PC. Success for Image means job security in Scotland. The Scottish workforce should give thanks that Polaroid reinvests so much of its sales income in research and development. Most Japanese electronics companies spend less than 5%; only Sony invests more than Philips of Holland which ploughs back just under 7%.

The new Polaroid Image System, now on sale in Britain and America (where it is called Spectra) uses radically new technology in both the camera and film. There is some hairy chemistry in the Image film and clever electronics in the camera's automatic exposure and focus control. Some will spin off into other products. Polaroid plans eventually to upgrade the film for its existing cameras and may license its new autofocussing system to other camera manufacturers. Like other modern Polaroid cameras, the new Image focusses its lens automatically by sonar. The transducer uses a single gold-coated Kapton polyester foil diaphragm which serves both as transmitter and receiver. When the shutter button is pressed the transducer emits a 1 milisecond pulse of inaudible ultrasound in a tight beam which covers 12% of the subject seen in the view finder. At the same time a crystal oscillator clock starts generating timing signals. These continue until the ultrasound echo returns. The counter then logs the echo delay. The sonar circuit outputs a control signal which adjusts the camera focus.

Conventional cameras adjust focus by moving several spherical lens members closer together or further apart. Image uses three lens elements, two fixed lenses and one a kidney-shaped panel which pivots between the other two like the moving filling of a sandwich. The central element is injection-moulded from methyl methacrylate (Perspex) and has a wavy contour like a rolling landscape. As it moves the combined optical effect of the sandwich changes from a positive power convex lens, for close up photography, through a neutral lens for middle distance shots, to a negative power concave lens for focussing on distant objects or infinity. The idea is old but made practical only by modern computing power. The new lens is called Quintic because there are five levels of polynomials in the two page formula and 88 mathematial coefficients needed to describe the wavy contour.

The sonar divides distance into ten focus zones, from a close up of 60cms to a medium distance 7.6 metres. When no echo is returned, it registers infinity. The moving lens element is latched in any one of ten positions, depending on the focus signal generated by the sonar. The ten focus zones overlap so there is effectively continuous focussing over the full range 60cms to infinity.

Exposure setting is also automatic; 13 integrated circuits make 30 decisions on lens aperture, flash power and shutter speed. The aim is to ensure that in daylight the flash still contributes a fixed 25% of the light illuminating the scene. This fills in shadows and eliminates what Polaroid calls the 'Rembrandt effect' – a flash-lit foreground subject with a pitch black background.

Unlike conventional cameras, the Image uses two, rather than one, photo sensitive diodes to measure the amount of light available for photographers. One diode has a light green filter and measures visible light reflected from the scene to be photographed. The other diode, with a dark red filter which blocks visible light, measures only infra-red and reads shades of grey. A combination of the two sensor readings gives the best average of the light reaching the film. Only a few materials fool the system. Cashmere wool for instance soaks up IR like a sponge to give a false reading.

Light from the flash is controlled by rapidly switching it off. The ICs juggle lens aperture (between f41.8 and f10), shutter speed (from 1/245 second to 2.8 seconds) and quench the flash after as little as 20 millionths of a second.

The system works digitally. When light strikes the dual photo diode, the analogue signal output is chopped into a train of digital pulses. The pulse frequency is proportional to the light brightness. When light levels are high, the flash is fired, but quenched very fast so that the photograph is taken with 75% flash light.

The shutter release works in two stages. Stage one sets focus, stage two opens the lens and exposes the film. The delay from pressing the button to exposing the film is only around one tenth of a second. Unused current for the flash circuit is recycled, so that the 22 watt flash is always ready to fire again in less than 1.2 seconds.

Image film uses new chemistry. Conventional instant picture film has three dye-developer layers, which are sensitive to red, green and blue light. The developers work by gating the migration of yellow, cyan and magenta dyes to a common layer where they mix to form a coloured image. The snag is that the dye-developer chemicals interact. Green often appears too dark.

The new Image film has conventional red and green dye-developer layers, but the blue-sensitive layer works on a quite different principle. It releases a yellow thiazolidine compound. The dye-developer and dye-release layers behave independently. There is no chemical cross-talk.

Film speed is high, 600 ASA, because maximum aperture is f10. So beware when taking Image film through airports. Some X ray equipment, especially in the USA, is only 'film-safe' up to 400 ASA.

Be warned also; for the time being only Image cameras will take Image films.

The camera can be triggered by remote control, using a 27MHz CB radio transmitter. As a neat touch, the camera can be set to retain the film after exposure. Normally the motor in a Polaroid camera noisily churns out the print immediately after it has been exposed. This can be embarrassing in quiet surroundings, for instance a church. So the new Image camera does not eject the film until the shutter button has been released.

Polaroid says it will consider licensing some of the new technology, for instance the novel focussing system, to other manufacturers provided their products are not in direct competition. Corporate policy bars exclusive licensing, however.

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We regret that lengthy technical enquiries cannot be answered over the phone.

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MY BIT AT THE BEGINNING – 7

I was very pleasantly surprised by the response to our l.c.d. competition announced in the November 1986 issue of PE. Both the quantity and quality of the entries was exceptional. We received hundreds of them from readers of all ages, levels of experience and walks of life. Some of the ideas that were proposed were extremely far-sighted and probably deserve more appreciation and recognition than we are able to give. However, at least one of the entrants will receive a pocket TV for the effort – we will announce the winner next month.

In our news pages last month we mentioned a little about education and the need for more suitably qualified people for industry. It was suggested that not enough students were attracted to science-based subjects and that the shortage of suitable science graduates may become greater in the future.

This problem is particularly acute within the electronics industry and in the short term this shortage may be true. I suspect, however, that with the introduction of the new O and A-level electronic syllabuses many more young students will become interested in technology and engineering based subjects. In a few years time, we will see far more people attracted to electronics in higher education.

The practical aspect of the new electronic courses in schools is encouraging students to be more self reliant, innovative and generally more interested in their subject. The massive increase in letters sent to PE by students asking for information about various projects, electronic devices or services reflects this. No doubt many people will disagree, but I doubt that students of geography, history or English, for example, are encouraged and motivated to the same extent.

This new found interest is good news for PE because we are now seeing our UK readership increasing due in part to the increase in electronics students in schools. I must point out however to any student reading this that PE CANNOT carry out your projects and rsearch for you. We do get a few letters from students who want us to research a particular subject, suggest a suitable design – in fact do everything short of building it for them.

Come on, don't be lazy, use your imagination in conjunction with PE and the library – it's much more rewarding in the long run.

Richard Barron

OUR MARCH 1987 ISSUE WILL BE ON SALE FRIDAY, FEBRUARY 6th 1987 (see page 30)

THE PE HI-STAB

BY MIKE DELANEY

A lab quality power supply

If you have ever needed a good quality bench p.s.u. for powering precision circuits then you have probably already realised the limitations of many basic units. This design offers an excellent specification superior to many manufactured supplies.

In most labs the power supply is usually the most used piece of test equipment, and consequently one of the most important. This supply is often a run-of-the-mill variable output type, of modest specification and price. It is not until it is called upon to power a strain-gauge or other precision bridge configuration that the limit of its spec. becomes glaringly evident. The type of supply required to drive TTL chips at 5 volts, +/− 500mV is not up to the precision demanded by a bridge circuit.

It is at this stage that it becomes evident that a much higher quality supply is required, and the HI-stab will suit most requirements.

As with any piece of test equipment, the ultimate quality is decided by the construction. The parts list calls for several high-specification parts, e.g. better than 1 per cent resistors. Where these are called for, 'Better Than' must be considered a necessary requirement, rather than the designer's flight of fancy, particularly if the unit's full spec. is to be realised. The first fully built and boxed version (as opposed to the usual birds-best of the prototype) gave the following results:

Warm up time to within 100μV of nominal: 45 minutes.
Short-term run round (noise): +/−20μV.
Drift from nominal (all ranges) over 24 hours: +/−100μV.
Recovery time to nominal +/−200 following short-circuit of 1 min, 10V output: 15 seconds.
Recovery time as above, 1V output: 1 minute.
Volt-drop under load conditions (3 metre leads, resistive load, maximum current limit 250mA): *10V output,* 100mA Load: -200uV; 200mA load: -850uV. *1V output,* 100mA Load: -700uV; 200mA load: -900uV.
These measurements were taken at the termination point of test leads at 3m distance from the instrument. The output leads used were lightweight hookup type 7/0.2.
These results were obtained by the use of a premium 5½/6½ digit meter.

All the above figures were observed with one specific power supply, and are meant to be a guide only to the possible results which can be obtained. They are certainly not guaranteed to apply to any other instrument, and should be treated accordingly.

THE BLOCK DIAGRAM

Fig. 1 shows the complete diagram.

The mains supply is reduced to around 25V d.c. in a conventional bridge before being reduced to 15V in a pre-regulator. This supplies the majority of the circuit. Output current sensing is taken off this line before it is applied to the mains series regulator. The reference voltage is divided down before being selected by an electronic switch. Control of this switch is achieved either on the front panel of the supply, or remotely via four input lines to the rear of the box. The divided down reference is taken to the difference amp, which in turn drives the output series regulator. The output is monitored in two ways. First the output current when in overload turns on an l.e.d. warning of this fault, and second, a hideously inaccurate moving coil meter is included. This latter only acts as a distant monitor, so you can see at a glance whether 1V or 5V has been selected – it is certainly not there to assist in calibration!

THE CIRCUIT

The mains supply is stepped down to about 25V d.c. by TX1 and REC1. Smoothing of this 'rough' d.c. is done by C1 and C2.

'Power on' is indicated by D12, which is powered by the a.c. low voltage side of the transformer. Current limiting and rectification is done by R36 and D10. D10 is required because l.e.d.s don't like being reverse-driven.

A pre-regulator, type 7815, then drops this to the system 15V. C3 is required since the regulator is mounted offboard, and should be a tantalum type, for its h.f. response. The circle with the '1' in it denotes that this is a single-point common. In this circuit there are two such common points, one for the pre-regulator and 'rough' supply, and one for the reference and low-current error amp circuit. Short circuit detection is carried out by R1, VR1, R2, IC2 and its associated components.

To monitor the current on the 15V line the op amp must be powered by a voltage

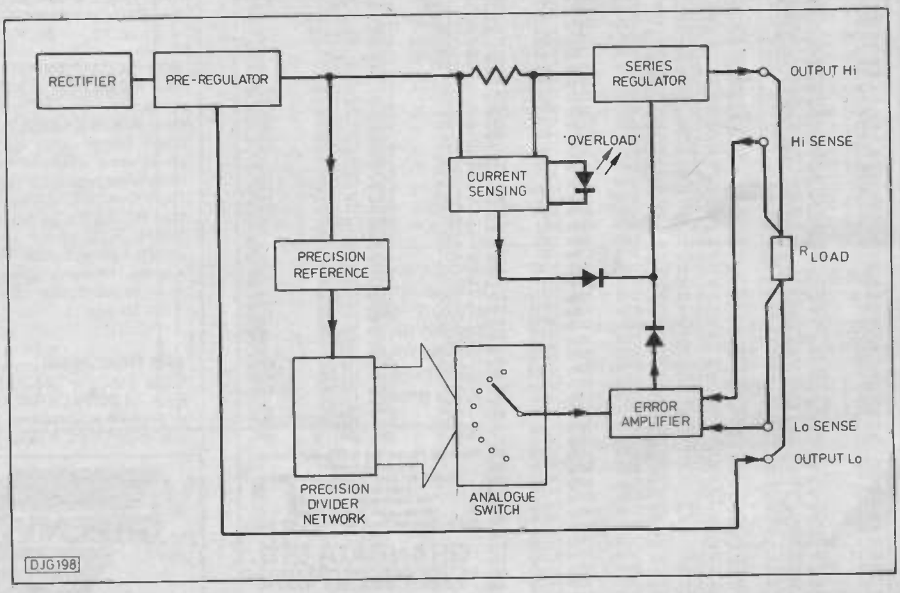


Fig.1. *Block diagram of the PE Hi-Stab*

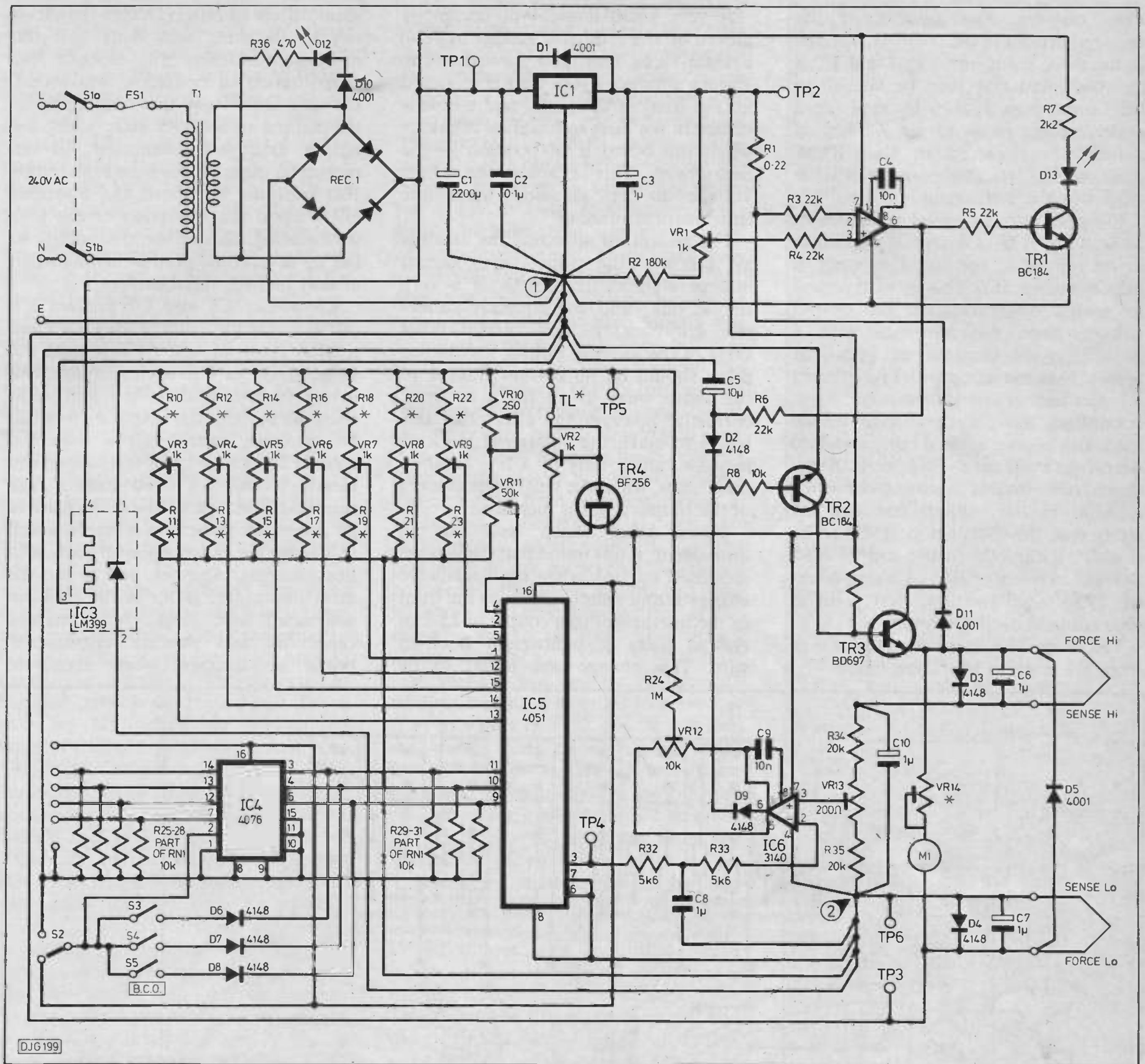


Fig.2. *Complete circuit diagram of the PE Hi-Stab*

higher than 15V. Hence IC2 is powered off the 25Vline, placing the 15Vline well within the operating limits of the amp. Sampling the output current at this point, rather than *after* the main output regulator allows the output impedance to be independent of the sampling stage.

With the values shown, the output short-circuit current may be adjusted from zero to about 350mA. In overload condition the output of IC2 goes high, to about 25V, turning on TR1 and lighting D14.

C5 charges and turns TR2 hard on via D2 and R8, which switches off the series-regulator, TR3. This is a standard constant-current type of limiting, and was designed in rather a fold-back style so that the supply could be used as a current-source as well as a voltage source. Also, at the level of current used here, the fold-back is not really worth fitting. Removing the fault will automatically allow the supply to recover, but refer to the accompanying tables. The heart of the power supply, and the reason for its stability, is IC3, an LM399 precision zener diode.

HOT STUFF

In order to achieve a very high degree of stability the LM399 contains its own oven. This operates at a temperature of around 85°C, so the casing feels warm to the touch. The manufacturers quote a temperature coefficient spec. of 0.00003 per cent per degree centigrade, and a stability figure, over 1000 hours, of 20ppm. Provided high quality components are used in the divider section recalibration should not be necessary very often.

TR4 and VR2 form a constant-current drive for the reference zener. TR4 should be selected to give a maximum D–S current of about 12mA, which will allow the pot to set the working current to 9mA; see below for setting-up details.

The zener voltage output from the 399 is nominally 7V. In the author's case it is 7.1450. This is taken to a series of eight divider networks, comprising R10 to R23 and trimmers VR3 to VR11. The values given for the fixed resistors apply to the particular 399 used by the author, as well as the output voltage required, and provided the total current drain on the reference is kept to less than 1mA, can be adjusted to suit individual needs.

The voltages from the dividers are applied to IC5, an analogue switch. Depending upon the BCD code on pins 9–11 this chip selects one of eight data inputs, outputting the selected voltage to pin 3. The BCD select code may be input to the instrument either locally, that is on the front panel via a switch, or remotely with IC4.

IC4 is a 4076, four-bit latch with tri-state outputs. The address of the required divider in BCD form is applied to the three input pins 14, 13 and 12 on the 4076, and may then be latched to the output pins 3, 4, 5 by applying a positive-going pulse to pin 7. Then, if switch S2 is placed in the 'REM' position, the selected voltage will be output by the instrument.

From IC5 the selected reference is filtered by R32, C8 and R33, before being applied to the inverting input of the error amp, IC6. This op amp is used to sample and compare the output voltage from the reference with a proportion of the output from the supply. In conjunction with TR2 it forms a feedback error-correcting loop, controlling the output voltage to the load. This is once again a fairly standard circuit, so I will not dwell upon it. If you should have trouble in sorting out which is what in the output, consider the emitter of the Darlington, TR3, to be connected directly to the top of R34, and the bottom of R35 as being direct to TP3, and you are left with a conventional output stage.

The diode D9 blocks the output high from D2 in event of a short circuit.

A very small amount of current is picked off the reference voltage by R24, a 1MΩ metal film, and applied to the 25-turn trimmer VR12. This is mounted on the front of the p.c.b. and a hole is drilled in the facia to facilitate tweaking when the board is in position in the instrument. This enables the offset voltage to be adjusted while the instrument is running.

The reason for adjusting the offset is as follows: the four wire system incorporated in this design is a very simple one, and consequently suffers one drawback, in that current flows OUT of the lo sense output. In essence there should be no current flowing in the sense wires at all for it to work correctly; however the effect that this has is to make the voltage at the load increase, albeit only by a few hundred microvolts, when the length (resistance) of the output leads is increased.

When doing bench tests on the instrument, it was found that the voltage increased by 1mV when the leads were changed from a short circuit on the front of the instrument to a couple of 25 foot twisted pairs of lightweight hook-up wire. This change was found to be identical on all ranges, hence the offset tweak. Tweaking was done and the instrument stability was checked. No deterioration in operation was found. D3 and D4 ensure that the supply is maintained in a stable state when the output load is disconnected. In the prototype these diodes were replaced by 10Ω resistors, but these had a serious effect upon the operation of the four wire sensing, causing the load voltage to fall by several hundred millivolts when at only half the rated current.

Capacitors C6 and C7 prevent h.f. oscillation in the event of long leads and a noisy environment. At first sight the value given for C10 seems wrong, with several 0s missing after the 1. Not so! In most lab supplies the output current will be generally much higher than the modest 250mA spec. for this supply, and clearly it will not need such a high reservoir. The type of loads which are to be driven are static and resistive, and it will never be called upon to cope with heavy surges. Another, and to me the most important, factor is the problem associated with large, fully charged capacitors and delicate instruments, prone to damage when asked to

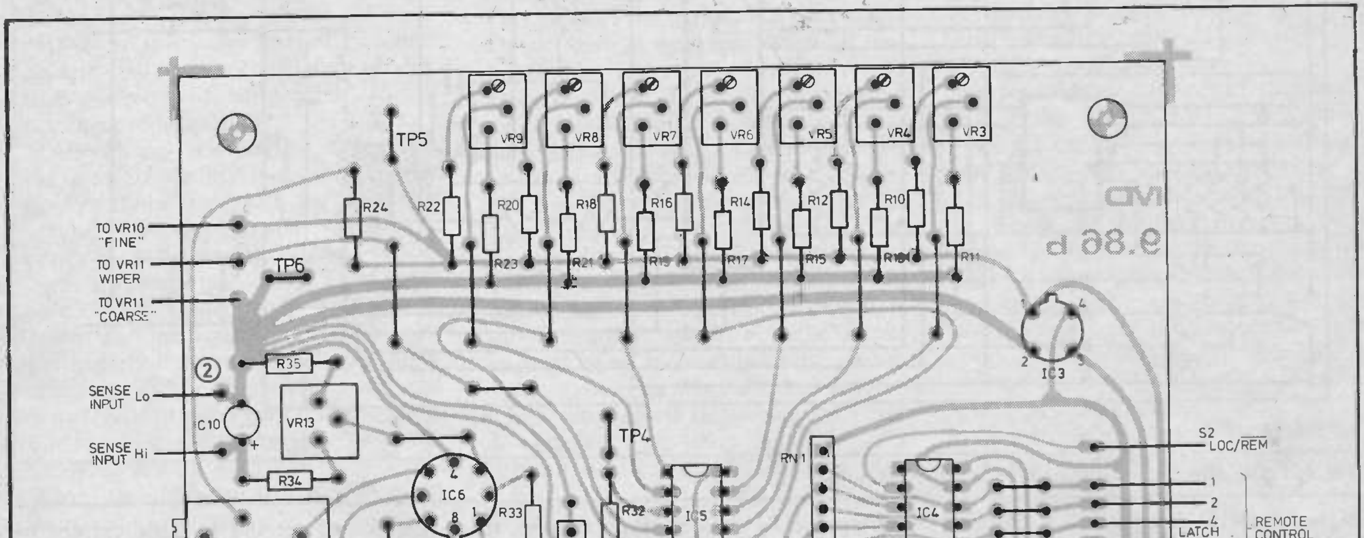


Fig.3. *P.c.b. layout of the PE Hi-Stab*

withstand heavy discharge currents. A few minutes spent with a calculator working out how many amps the instantaneous current is when 10,000μF is charged to 10V loop stability is such that a μF is quite sufficient. The roll-off capacitor C9, round the error detector, ensures that. Increasing C10 to 22μF slowed the loop response to such an extent that settling times at switch-on or following a short-circuit were increased considerably, and could take up to ten minutes to get within 500μV of the correct output.

In a lab environment it is always possible to connect a lead to the wrong place! To help safeguard the instrument, three diodes have been fitted: diodes D1, D5 and D11 will prevent all but the worst type of accidental connection from damaging the instrument. I cannot say what might happen in the event of the mains being connected to the output leads, I should expect the result to be none too pleasant, so don't be tempted to try.

The prototype was fitted with eight preset output voltages, and a lot of time was spent twiddling one or the other to obtain a different voltage. In the present version, one channel (7) is connected to variable pots on the front panel. These two are both precision wire-wound types: VR10 is a 250Ω single turn, and VR11 is a ten-turn, 50Ω. This combination will allow the output to be continuously varied between about 100mV and 14V, with a resolution of 100μV. The output voltage is sampled by R34, VR13 and R35. I have specified very good resistors here for obvious reasons. The stability of the whole depends upon the sampled voltage, and if this is allowed by the resistors to drift the instrument will never function correctly. If 0.1 per cent resistors are not available it will be necessary to match them from a selection, otherwise the value of the trimmer VR13 may need to be changed.

The absolute values for R34 and R35 are not critical, but they must be matched, of very low t.c. and of the same type. Although the version shown uses a preset control in the current setting position, VR1, it is also quite possible to replace this with a variable potentiometer mounted on the front panel, thus increasing the versatility of the instrument.

CONSTRUCTION

The circuit is laid out on a single p.c.b. which should not present any problems to the constructor. If you should decide to use a board of your own design (shame on you!), make sure that the commoning methods are adhered to, otherwise you will be designing in offsets which you may not be able to get rid of later.

Regulator IC1 and TR23 are not mounted on the p.c.b. but on a false bottom made of a heavy gauge piece of aluminium mounted inside the case. This chassis is a heat buffer, there only to act as a temperature sponge. Temperature differences across individual resistors can cause offsets to be generated (thermo-electric effect), so mounting the 'hots' to a buffer helps even out the effect of shorts on the output and so on. The leads to both these components should be kept short, and they should be positioned an inch or so away from the board. The board consists of a 'hot' side and a 'cold' side. The mains transformer and switch should be mounted to the hot side. The 'cold' side is of course the side holding the reference dividers. The 25 turn pots in this divider have been mounted along one side of the board. Should you wish, it is possible to position the completed board in the case so that these trimmers can be turned from outside the case.

Use an i.c. socket for IC4, but mount IC5 directly to the board. In the prototype it was found that the socket could cause the reference outlet to jitter by an appreciable amount. Tracing the cause to the socket took more than a minute or two!

If you do not require the remote facility, it is quite in order to leave out IC4, in which case S2 can be left out, with the BCD switch centre wiper wired to +15V. D6, D7 and D8 can be replaced by shorts of tinned copper, but the resistor network *must* be fitted, in order to pull the control lines low when the switches are open.

Several test points have been included to make subsequent fault-finding easier, and should be formed from 22 s.w.g. tinned copper wire and fitted where indicated. Also included in the testing is the Test Loop 1, adjacent to f.e.t. TR4. This should be fitted and then *cut*, and the two ends carefully separated. This *must* be done before power is applied to the circuit. Failure to do so can damage the 399. See the setting up section below.

Diodes D1, D3, D4, D5 and D11 are also mounted off-board. D1 and D11 are carefully formed and soldered directly to IC1 and TR3 respectively, while D3, D4 and D5, along with C6 and C7 are mounted to the rear of the output terminals. The meter and its associated trimmer are mounted separately also.

Resistor R1 is a ½W wire-wound, and is fairly large. The holes in the p.c.b. are spaced to accommodate this. The legs of this resistor should be formed, and then the whole mounted so as to leave about a quarter inch clearance between the resistor body and the surface of the board.

To assist with setting up later it is advisable to fit the links from the eight dividers so that it is possible to clip on a test lead.

TESTING

When assembly is complete, have a

COMPONENTS . . .

RESISTORS

R1	0.R22 ½W, wire wound
R2	180k ¼W5%
R3,R4,R5,R6	22k ¼W5% (4 off)
R7	2k2 ¼W5%
R8	10k m.f. 1%
R9	3k3 ¼W5%

R10 to R23 inclusive: see separate list below.

R24	1M m.f. 1%
R25–31	RN1, 7 x 10K resistor network, in s.i.l. package
R32,R33	5k6 m.f. 1% (2 off)
R34,R35	20k 0.1% Wire Wound (2 off)
R36	470R 1W carbon 5%

POTENTIOMETERS

VR1,VR2	1k cermet 1-turn trimmer (2 off)
VR3 to VR9 inclusive	1k cermet 25-turn trimmer (6 off)
VR10	250R W/W (RS 173–186)
VR11	50k 10-turn W/W, 40 p.p.m.
VR12	10k 20-turn ¾in cermet trimmer
VR13	200R 1-turn cermet trimmer
VR14	Select to suit meter

CAPACITORS

C1	2200μ/40V
C2	100n metal polyester
C3,C6,C7,C10	1μ/35V tant (4 off)
C4,C9	10n disc (2 off)
C5	10μ 16V tant
C8	1μ polycarb

SEMICONDUCTORS

D1,D5,D10,D11	1N4001 (4 off)
D2,D3,D4,D6, D7,D8,D9	1N4148 (7 off)
REC1	WO-01 bridge
D12	0.2in green l.e.d.
D13	0.2in red l.e.d.
TR1,TR2	BC184
TR3	BD697 Darlington
IC1	78M15 regulator
IC2,IC6	CA3140 op amp (2 off)
IC3	LM399 precision zener
IC4	4076 quad latch
IC5	4051 analogue switch

MISCELLANEOUS

T1 Transformer, 240V primary, 18V at 20VA secondary; fuse, 20mm, 250mA A/S with panel-mounting holder; S1, d.p.d.t. rated 250V a.c. at 3A; S2, s.p.d.t. miniature; S3, S4, S5, 1 off BCD edge switch, RS337–453 complete with pair of end cheeks; output terminals to suit leads in use, complete with solder tags; mounting hardware for l.e.d.s (2 off); collet knob (2 off); IEC mains input socket with lead; REM output socket to suit equipment in use; case to suit (the one illustrated is RS type 501-610); p.c.b.; hook-up wire, nuts, bolts, etc.

close look on both sides of the board to check for errors. Check that TL1 is cut and the ends are not touching.

For the preliminary checks it might be as easy to leave the regulators off the chassis, but wrap a piece of tape round each to prevent them shorting anything.

For these initial stages of testing use a bench supply, set to 25V at 500mA, and leave the transformer disconnected. Connect the bench supply to the a.c. input pins on the rear of the p.c.b. and check the regulator is giving 15V, and it is not getting sweaty.

Set VR1 to centre, and check the overload l.e.d. is not lit. Connect a d.c. milliampmeter from VR2 side of TL1 to common 2, and carefully turn VR2 to give a current of 9mA. Leave the probes connected for a while and check that this remains as set, and does not fluctuate.

When satisfied that this is working, power down and solder the two ends of TL1, and seal VR2 with a spot of paint. Reconnect the supply and check the reference voltage at TP5 with respect to common 2. This needs to be done with a high-resolution digital meter, and should be measured to 100μV. Check that this voltage is stable to within that degree and does not run round. If it should appear noisy, use a scope to try to find the cause.

Gently touching the casing of the 399 should reveal it to be quite warm (not hot!) to the touch. If it is not, and provided the device is mounted correctly, then it is probably faulty.

After about a minute the reference voltage should be absolutely stable, and should be noted.

Using this value, it is now possible to calculate the values of the divider resistors. These should be calculated so as to give a total of 100μA in each leg, and so 100mV across each preset, and exactly half of the required output voltage on the wiper when it is in the centre. Easier said than done! I have a couple of foolscap pages of jottings, and it will prove to be a compromise in most cases.

Accepting that an output of 1.0000V is required, R10, VR3 and R11 are set to give 0.5000V at pin 13 of IC5. With S2 and S3 to S5, select LOC and 000. Check that TP4 is also at 0.5000V. There may be a slight discrepancy here, if so adjust VR3 in order to give the correct output at TP4. Looking now at the output, ensure the sense inputs are shorted to their respective force outputs, using a short piece of wire.

Centre VR13 and VR12, and check the output voltage is 1.0000V +/− 100mV. If it is somewhere within striking distance at this stage it is good enough.

Fit the remainder of the resistors in the precision divider checking each leg as you go. It will probably be necessary to make series or parallel connections to get the fixed resistors exactly right. 1 per cent metal film or better should be used throughout, and metal films used for trimming. Check that turning the offset pot, VR12, gives a corresponding change in output of around 200mV both positive and negative with respect to nominal. VR13 should also be checked. Using wire links, check that IC4 works in REM, if fitted. The output should change only after the input code has been strobed through the latches by taking pin 7 high.

Slowly turn VR1 anti-clockwise, and check the overload l.e.d. comes on when the pot is near or at the extremity of travel. Connect the current meter, select the 1A range and slowly rotate the limit pot clockwise until the output current is set at 250mA. Do not keep it running long though, the regulators are in free air, and will soon get quite hot. When all these preliminary tests have been successfully carried out the p.c.b. can be mounted into the box, using plastic spacers and being careful not to short any tracks. Both regulators can be bolted down, with a smear of thermalpath on each. The BD697 *must* be isolated from the chassis with a mica washer and collar.

Connect the low voltage side of the transformer to the board, and the power on l.e.d. R36 and D10 are isolated to one of the output tags on the low voltage side of the transformer, and should be isolated from chassis by slipping a piece of insulating sleeving over them.

CALIBRATION

Switch on the instrument and allow it to warm up for at least an hour, with the lid on.

Start with the lowest voltage first, for example 1.0000V. All calibration is done with the output off load, and the force and sense leads connected at the output terminals.

Allowing as little air movement as possible, connect a digital voltmeter to common 2 and TP4. Adjust VR3 to give a reading of 0.5000V. Leaving the leads in place and replacing the lid of the instrument, check that the voltage at TP4 remains within 100μV of this.

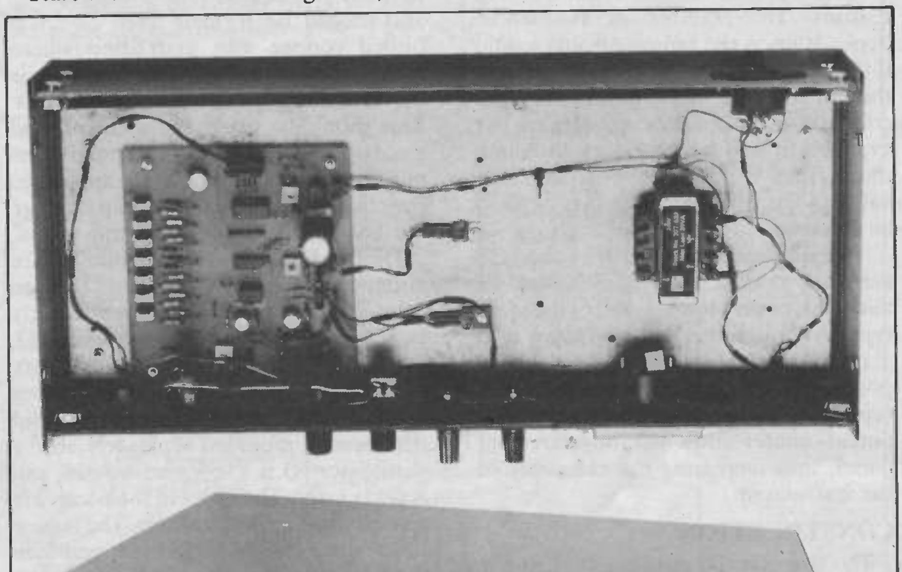
Repeat with VR9, setting TP4 to 5.0000V to give an output of 10.0000V. Again, sit for a while and make sure the voltage remains stable.

Recheck 0.5V, and then 5V after a few minutes. Set VR12 to centre travel through the hole in the front of the instrument, and set VR13 to centre.

Select 10V output and connect the meter to the output terminals. Adjust VR13 to give exactly 10.0000V. Select 1.0000V output, and very carefully adjust VR12 to give this voltage.

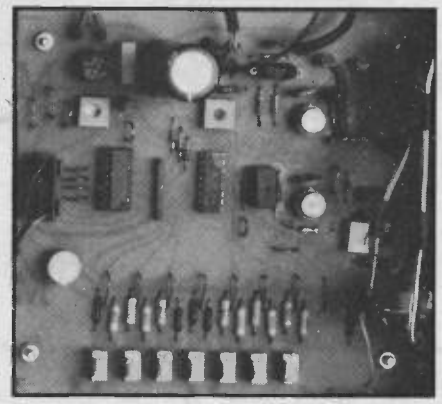
Reselect 10V and again adjust VR13. Repeat these two steps until both are reading correct to within 100μV. Having got these two set correctly, adjust the remaining trimmers in the divider to give the required outputs. Should it be necessary to trim any of the resistors by soldering in another resistor, power down first and allow enough time after these adjustments for the components to cool or to heat as necessary. With the trimmer values used this should not be quite as long-winded as may appear; it hinges upon the quality of the components used.

Remove the shorts from the output terminals, so that the force and sense



leads are allowed to float. The output should increase by about 1.2V, that is the forward drop of the two diodes, D3 and D4. Connect two pairs of output leads of about 10 feet in length. The output at the junction of these will now be higher than the nominal by perhaps about 1mV. Check that this is so on all ranges. If it is not, and tends to have a linear offset to one end, return to setting up VR12 and VR13 as above. If all is well, the tweaking VR12 through the front panel should bring all the voltages back to their nominal settings, +/ -100μV. With long leads connected check the four wire sensing is working correctly as follows.

Select 10V output, connect the DVM to the remote junctions of the leads, the 'load' point, connect a 50Ω resistor to the output and check the voltage does not drop by more than 100μV. Repeat, this time with a 33μ, and check the output limits and the overload l.e.d. turns on. 'Scope the output in parallel with the meter and check that it is stable, and does not burst into oscillation at any time. Check slow-recovery is working following a shorted output. With the 'scope on 10mV/cm, a.c. coupled, and sweep speed 100mS per cm, short the output, and monitor what happens when the short is suddenly removed. In order to carry this check out properly it will be necessary to trigger the 'scope off the rising edge. There should be no appreciable recovery overshoot; if there is, check that R6 and C5 are correct, since these are the components which should prevent this fault.



This completes the calibration. How often the instrument will need to be recalibrated will depend upon the components used. Perhaps the best approach is to monitor the outputs closely after an initial period of, say, a month, after which time most of the stresses put in at construction will have disappeared, and the instrument will have settled down. Noting each output on a graph, with 100μV divisions is a successful approach used by the author. It helps highlight any 'rogue' resistors in the precision divider. I think the 'calibration' of the moving meter I can safely leave to you to sort out.

I must stress that this is *not suitable* in its present form for connecting directly to the human body. This type of power supply requires a different mains transformer, and mains connection methods. There are various regulations governing this type of usage, and as a first step I would recommend a visit to your local reference library.

With a reference of 7.1450 volts at TP5, WRT TP6, and in order to obtain output voltages of 1V, 2V, 3V, 4V, 5V, 7.5V and 10V the following values of resistors were used:

R10	62k	R1	4k7
R12	62k	R13	10k
R14	56k2	R15	15k
R16	47k	R17	18k2
R18	39k	R19	21k
R20	33k	R21	36k5
R22	22k	R23	51k

In each case the trimmer (VR3 to VR9) is a 25-turn 1k cermet. When choosing values proceed as follows:

a) measure accurately Vref
b) decide on preset outputs required
c) calculate value for upper resistor so that the voltage at the top of the trimmer is:

$$\left(\frac{V_{\text{preset output}}}{2}\right) +50\text{mV}$$

$$\text{when } I_{tot} = 100\mu A$$

The value for the lower resistor is then easy to calculate. By using preferred values for the top resistor, it is made more difficult to arrive at an easy solution for the bottom resistors, but this is a compromise throughout. It is important to use m.f. types, even for trimming purposes.

LOW DROP-OUT PSUs

BY B.J. FROST

A good natured battery

A look at low-cost alternatives to mains powered bench power supplies. In this feature we show how, using modern components, a battery powered supply with voltage and current limits can be designed.

MOST experimenters spend the early stage of their hobby using a battery for a power source, as it is a readily obtained, reasonably stable source. At some point the experimenter may build or buy a bench power supply which provides more flexibility and more protection for the circuit. But even the owner of a bench power supply returns to consider the humble battery when a small, perhaps low-powered, circuit is to be tested away from the bench; constructors of radio gear, for example, will know the problems of operating such circuitry with a bench supply in any case, let alone when tests remote from the bench and its mains outlets are required.

While a battery is a handy power source, it is often expensive, usually runs out when needed most and, if it is a rechargeable type, can provide relatively high short circuit currents sufficient to damage circuitry that would be protected by a current limited bench supply.

This article describes a low voltage drop, low consumption regulator circuit which can be added to any type of battery to provide an adjustable and stable voltage with full current limiting facilities of up to 20V at 1A. Its current limiting facilities will prove essential to experimenters inclined towards the use of lead-acid batteries!

For its ability to tame a potentially dangerous battery current into a convenient power source, the complete unit may be termed 'the good natured battery'.

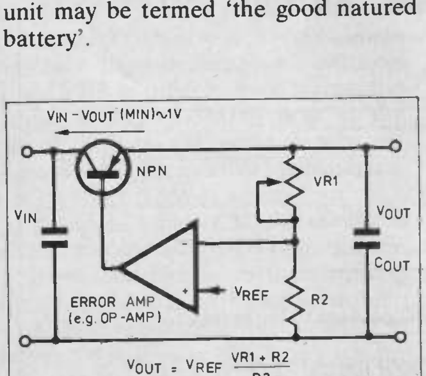


Fig.1. *Conventional form of regulator*

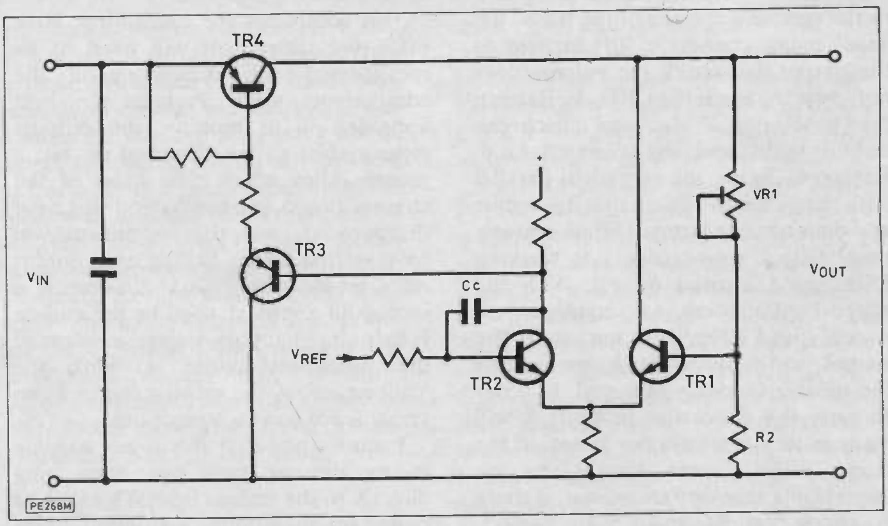


Fig.3. *Low drop regulator with simple, stable error amplifier*

VOLTAGE SOURCE

The ease with which a battery can be a successful, general purpose voltage source depends on the type of circuitry being used. CMOS logic, with its wide voltage tolerance and its low-power consumption, is well supplied by almost any common battery, as also are most analogue and discrete circuits. Faster logic circuitry such as LS, TTL or HCMOS is more restrictive on the supply rails, as well as being more current-thirsty, so these circuits must have their required supply voltage maintained for varying current demands, without the benefit of an additional regulator.

Choice of battery type is often arbitrary. Rechargeables are now readily available in both Ni-Cad and Gel type lead-acid styles. These are tempting, but the user pays the penalty if a fault exists in the circuitry, when the battery may be able to supply several tens of amps into the circuit with disastrous results.

It is soon clear that for many circuits there is no ideal 'experimenter's' battery, and in some cases there may be no battery at all that can provide, say, 5V within the permitted supply rail variation without the use of an added regulator to complicate it. It becomes clear that there would be a use for a unit

Users of a good bench supply will appreciate the benefit of a selectable current limit control that allows a current limit to be set from about 50mA upwards. This permits an initial low setting while the circuit operation is checked before increasing the current limit toward the normal operating point. Under these conditions almost every dangerous circuit fault will remain to be observed without any damage. For the stunt men of electronics who solder their circuits with the power on, such a current limited supply is about the only safety net.

The quest is on, then, for a regulator that allows its output voltage to be adjusted easily, its output current to be

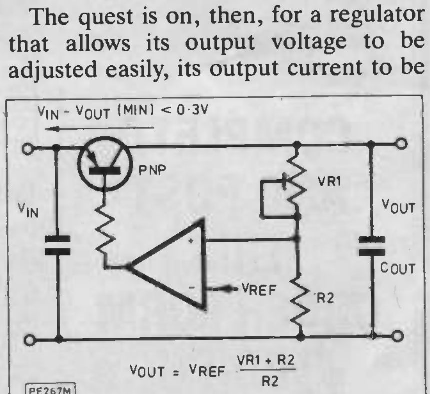


Fig.2. *A typical low drop regulator*

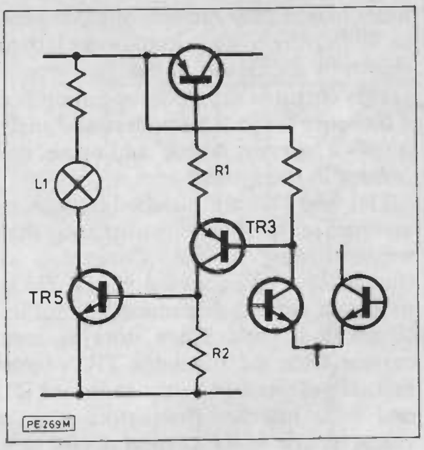


Fig.4. *Adding an unregulation indicator*

controlled, and which operates with a minimum of voltage drop. These requirements are not yet satisfied with an i.c. regulator but a simple regulator can be fabricated from components that can be tailored to suit the user's application.

REGULATORS

It may be of interest to describe existing regulator techniques before moving on to the low-drop types. The most common type of voltage regulator is the series dissipative version shown in Fig. 1.

This uses an NPN series-pass transistor (for +ve output) which is controlled by an error amplifier (e.g. an op-amp) which compares a portion of the output voltage with a fixed reference voltage Vref. Any difference between these two results in the pass transistor following the output of the error amplifier and adjusting the output voltage accordingly.

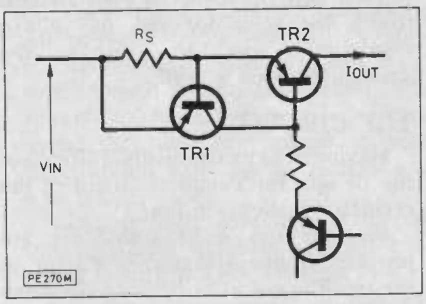


Fig.5. *Conventional current limiting*

that combined the portability of the battery with the flexibility and protection of the bench power supply, either to supplement an existing bench power supply or provide one if no other existed.

The simplest method of battery conditioning is to add one of the readily available fixed regulators such as the 7805 to provide a fixed 5V at about 1A max. These regulators provide a very stable output voltage at any output current up to the 1A limit, at which the regulator reduces the output voltage to fix this 1A current. This current limiting is probably more important when used on a potentially high-current battery than the ability of the regulator to stabilise the voltage. For applications where a non-adjustable 1A current limit is satisfactory these regulators are ideal and the only other characteristic to be wary of is the minimum drop-out voltage. All the common regulators require at least 2V across them to ensure that their internal circuitry will function. The choice of battery will need to take this increased voltage into account.

More recently one manufacturer (National Semiconductor) has brought out a small family of 'low-drop' regulators which can operate with a differential of under 0.5V. Use of these devices is unfortunately restricted due to the high value of output capacitance required for stable operation, limiting its use when testing delicate circuitry in safety.

towards explaining why they require around 2V for their operation. When the regulator is supplying current, the base of the pass transistor must be approx 0.7V above the output emitter. In addition, the error amplifier output loses some 0.3V in supplying the base current required by the pass transistor. Add to this the internal current limiting function which uses a sensing transistor base-emitter to detect the output current, and the figure is already around 1.5V. Implementation of the circuit on the i.c. adds more transistors than described making this 1.5V slightly optimistic.

One way of reducing this voltage drop is to turn the pass transistor into a PNP device as shown in Fig. 2. This enables us to 'pull' base current down out of the base of the transistor to turn it on. As it turns on, its collector (the output) can rise in voltage until it is within some 0.3V max of the input emitter, despite the fact that the base is already some 0.7V below

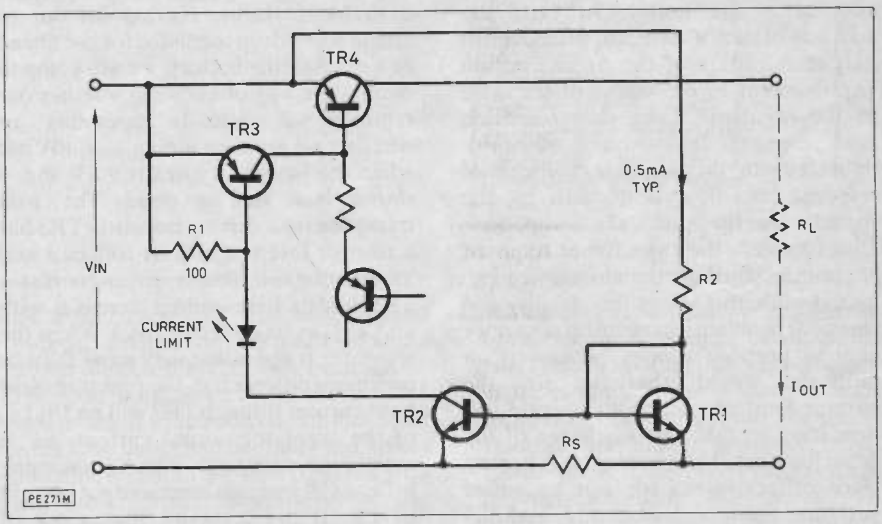


Fig.6. *Low voltage drop current limiting detection*

This simple regulator works well in practice and with relatively few components since stability with this form of circuit is quite easy to achieve. Evidence of instability is an unwanted oscillation on the output of the regulator caused by its feedback voltage undergoing too great a phase change as it passes through the error amplifier, and this occurs usually at frequencies in excess of 100kHz (or even higher for commercial regulators) as well as varying with loading. The circuit of Fig. 1, however, tends to be stable without any special precautions due to the fact that the pass transistor is connected so that it simply buffers the output of the error amplifier and provides no voltage gain, only current gain. This leads to the frequency performance of the circuit being governed largely by the error amplifier alone, and since most general purpose op-amps are inherently stable for low closed-loop gains, the circuit as a whole tends to be stable.

This principle is used in all the popular '78' series regulators and goes some way

the input. In this way a low differential has been achieved.

Note that the error amplifier has its input terminals reversed. This is because the pass transistor now inverts all actions at its base and we must preserve negative feedback.

Unfortunately, the circuit has a stability problem. Since the pass transistor is connected in common-emitter mode (its emitter at the input sees a low impedance to ground) it adds its gain and phase shift to that of the error amplifier in such a way that the compensation internal in the error amplifier is no longer adequate as it is in Fig. 1. This instability results in oscillation at the output which varies with loading and which must be removed by one of two main techniques.

The first method is to cause the error amplifier to roll-off its frequency response even earlier than usual in an attempt to make this the most dominant effect on the closed loop gain. This result of turning the amplifier into an integrator by adding a capacitor to 'slug it' is a technique that can be used to stabilise almost anything, but the price to be paid is seen when a load change occurs, say from on-load to off-load. The result of this is an overshoot at the output that may be several volts before the supply corrects itself. Such performance is often described in the data sheets as 'settling time', 'overshoot' or 'undershoot'. The worst of these is the overshoot in which the circuit under test may be subjected to an overvoltage pulse of a few milliseconds duration significantly above its permitted supply rail maximum.

The second method is to reduce the overall power-supply gain at the frequency of oscillation by the addition of a load capacitor to create an a.c. load that approaches zero impedance at high frequencies. Since the common emitter connection of the pass transistor provides a gain directly dependant on the load impedance, the lower the load impedance the better. In fact, the addition of such a capacitor provides not only stabilisation of the circuit, but an improvement in the transient response of the regulator, since short duration load changes that would otherwise interact with the regulator's speed of response are now dealt with by the stored energy in the capacitor. Unfortunately the capacitance required is around 100μF for the circuitry of Fig. 2, and while this solves the stability and transient problem it now results in a poor general purpose supply, as any circuit fault that would otherwise cause the current limit protection to operate will now have to take the discharge of the capacitor first. This problem is inherent, since no series resistor can be added without again running into stability problems.

Clearly some kind of compromise is required, and it is here that we can weigh our requirements against the possible tradeoffs. For a commercial low-drop regulator these tradeoff decisions have already been made for us, and they specify the requirement for a 100μF output capacitor to guarantee stability. In return they offer a very stable voltage due to the high internal error amplifier gain and a current limit that is intended as a safety feature rather than for routine use. The transient and stability performance is very good, but is due almost entirely to this output capacitor.

For a general purpose bench supply the current limit facility is much more important and, if available, will probably be used repeatedly. In this case the stored energy at the output of the supply must be kept to a minimum requiring, say, a 0.1μF capacitor only for h.f. decoupling. For this approach a stability solution is to have less h.f. gain internal to the regulator by using a circuit as shown in Fig. 3. This is one of the situations where discrete construction can actually improve on the i.c. equivalent.

In the circuit of Fig. 3 a long-tailed differential pair comprising TR1 and TR2 compares a portion of the regulator's output with the voltage reference 'Vref'. Any difference between the two causes the pass transistor base current to be varied via the buffer stage TR3. This closed loop has sufficient gain to keep the output voltage constant for varying input voltages and yet it provides a good bandwidth. It is this bandwidth, combined with moderate gain, which makes for a stable closed loop. To ensure stability with various loads a compensation capacitor is fitted around TR2.

This circuit has a limitation in that output control is only adjustable down to about 1V, but this has not been found to be a problem.

For a bench supply there are other desirable features. Having set out to create a low-drop regulator for use ahead of a discharging battery, we are going to need some way of knowing whether our regulator is actually operating or whether we are demanding, say, 10V out when the battery is already 9.8V. Fig. 4 shows how this is done. The pass transistor base driving transistor TR3 has a resistor inserted into its collector and an additional indicator driver transistor TR5 has its base-emitter across it with an l.e.d. as its collector load. When the regulator is operating with more than its minimum differential, the pass transistor base current through TR3 will be 1/h.f.e. of the regulator output current, i.e. a maximum of about 20mA, assuming h.f.e. of 50 and maximum output current of 1A. If the regulator moves out of control due to the input voltage being inadequate, TR3 is immediately pulled down to obtain the maximum base current that can be obtained for the pass transistor. This overdriving of the base can easily be detected by R2 and TR5 to operate the l.e.d. to signal 'unregulation', usually a difficult facility to provide.

What about the current limiting action that I made so much of earlier? See Fig. 5. This shows the popular way of obtaining current limiting in a very simple and effective manner. A sensing resistor (Rs) is inserted on the emitter side of the pass transistor (TR2) and a clamping transistor (TR1) shorts the base emitter junction of the pass transistor if the current exceeds Ilim × Rs = 0.5V. This limit is slightly temperature dependant but is fast in operation and various values of Rs can be switched in for various limits. If this circuit is added to Fig. 4 it will however add some 0.5V to the minimum drop required when operating near the current limit. This can be reduced by accepting a current limit that is several times higher than the operating current, or by moving to the alternative method shown by the circuit in Fig. 6.

This circuit is simple in operation but a bit more difficult to understand since it uses a 'current mirror' and senses the current in the ground lead.

TR1 and TR2 are matched transistors and part of the 3046 transistor array that we are going to use. Connected as shown, TR1 is a forward biased diode passing a current determined by R2 up to about 0.5mA. When drawing zero current from the regulator, TR2's base-emitter voltage will be the same as TR1, and with matched transistors it is a characteristic of the current mirror that TR2's collector current will also be close to 0.5mA, i.e. TR2's collector current has 'mirrored' that of TR1. This bias current develops a voltage across R1, the base-emitter resistor of TR3 (the pass transistor clamp) with insufficient voltage to turn it on. When a current is drawn from the regulator a voltage is developed across Rs and this has the effect of upsetting the unity mirror ratio of the current mirror. A voltage of about 40mV across Rs is sufficient to change the mirror ratio by one decade, increasing TR2's collector current to 5mA, just enough to begin to turn TR3 on and the regulator off. This current limit voltage threshold is a factor of ten times lower than one base-emitter, used as a comparator, can offer.

Another desirable feature of this circuit is the indicator l.e.d. that shows the state of the current limit. Used in this fashion, the l.e.d. glows faintly at zero current and brightens up quickly as the current limit is approached. Operation at or exceeding the current limit is easily seen, because when TR3 starts to turn the regulator off, its action forces the regulator out of voltage regulation and so brings the 'unregulation' on as well.

THE CIRCUIT

Having described individual aspects of the design, the complete circuit of the regulator is shown in Fig. 7.

Five of the eight transistors are provided from a 3046 transistor array, so the ciruit is not as difficult to construct as might be thought.

The voltage reference Z1 is ideally a 1.2V 'band-gap' reference. These are effectively 1.2V zeners, but with a very low change in voltage for any given change in operating current (slope resistance). The best device is the 9491 from R.S. Components, which operates from 50μA, and this allows the quiescent current of the entire unit to be only a few milliamps. Other devices such as the Ferranti ZN423 or even a low voltage zener diode may be used as long as the resistor is altered to provide a suitable current and so any reference can be applied to TR1 with the limitation that

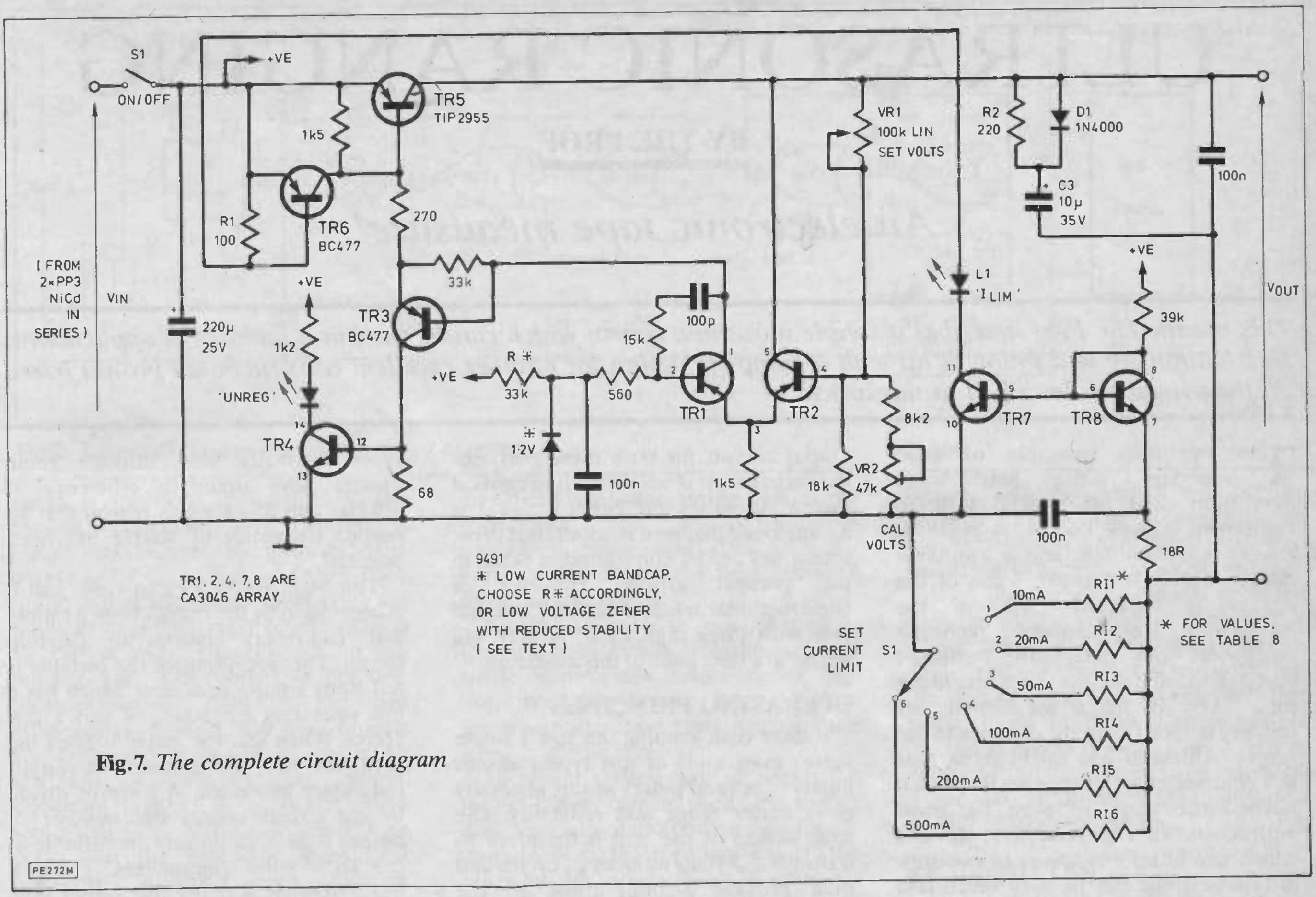


Fig.7. *The complete circuit diagram*

whatever the voltage, this will be the minimum to which VR1 will reduce the output voltage.

This reference is compared with a portion of the output voltage divided by VR1 (set output voltage) and the VR2 network as a trim adjustment which can be used to set VR1 maximum to 15V. VR1 can then be marked with the desired voltages and its minimum setting will be the reference voltage 1.2V. More accurate voltage settings could use a rotary switch instead of VR1, but I find smooth voltage adjustment to be more useful than absolute voltage accuracy, which in any case can be checked with a meter.

TR3 applies the base drive to the pass transistor TR5 which is a plastic PNP power transistor. TR3, TR5 and TR6 are

RESISTOR VALUE = $\frac{90}{I_{LIM}(mA)}$, BUT ALLOW FOR SWITCH RESISTANCE

SWITCH	CURRENT LIMIT	RESISTOR (S)
1	10mA	2×15 PARALLELED
2	20mA	2×2R2 SERIES
3	50mA	1R8
4	100mA	2×1R8 PARALLELED
5	200mA	0·33
6	500mA	3×0·33 PARALLELED

IF CURRENTS ALL REQUIRE ADJUSTMENT TO ACCURACY <10%, R1 (100) MAY BE VARIED — LOWER TO INCREASE CURRENT.

PE273M

Table 1. *Sense resistors*

all PNP transistors and any general purpose devices for TR3 and TR6 and a power device for TR5 will be suitable. The loop is stabilised by C2 around TR1 in a position which will be familiar to all who have built audio power amplifiers and there should be no problems with the stability with reasonable layout, but C2 could be increased if necessary.

TR4 and its l.e.d. load sense TR5's base current to detect when the regulator loses regulation, an abrupt point found for example when VR1 is set to a voltage within 0.2V of the input voltage or when the supply discharges to the point of unregulation.

The switch S1 switches one of six sensing resistors into the current mirror TR7 and TR8 offering fixed current limit settings from 20mA to 1A acting through the current limit indicator l.e.d. L1 and the clamp transistor TR6. These current limit settings are not precise but could be adjusted more closely by varying R1. Also if required other currents may be chosen by altering the switch resistors specified.

C3,R2,D1 is a network that improves the transient response of the supply. Output capacitors should be avoided to ensure that no charge can be dumped into the circut under test, but use of the diode and resistor ensures that while C3 cannot discharge current pulses into a fault, it acts as a clamp for short duration voltage pulses created when the load reduces its demand.

The unit as it stands is designed for operation from around 15V, supplied by two PP3 type NiCad batteries connected in series. In its present state operation from 12 to 18V should not require any changes. The circuit, however, may be modified say, to supply 5V logic systems.

When changing this resistor, the 'unregulation' sense resistor (currently 68) should be changed such that normal operation of the regulator (i.e. a base current of Iout/h.f.e.) provides around 300mV across it. This ensures that the unregulation sense transistor is not yet turned on and only becomes so when the unregulation condition exists.

If other current limit setting is required it is only necessary to change the resistors that perform the sensing. Determination of the values is best done by trial and error since the sensing voltage of 90mV is not precise but will change at significantly different input voltages unless the 39k mirror bias resistor is scaled to maintain the design current of around 0.3mA.

Some typical current limit resistor values are shown in Table 1 but to ensure satisfactory operation at currents above 200mA it will be necessary to use a two pole, six way switch with both poles paralleled, since at these low resistance values the switch resistance can become significant. Attention to the method of connecting the current sensing is also important at these upper currents. PE

ULTRASONIC RANGING

BY THE PROF

An electronic tape meausure!

This month The Prof describes a simple ultrasonic system which can be used in a number of applications. Next month we will follow it up with a complete design for another excellent constructional project based on the principles described in this article.

THE operating principle of echo sounders, radar, bats' sonic navigation, and other echo location equipment is well known. A pulse of energy is transmitted, and if a suitable 'target' object is present, some of the energy is reflected back to the transmitter. Here, suitable receiving equipment can detect the reflected signal, and logic circuits can measure the time taken for the signal to make its journey and calculate the distance to the target. Although you might think that any equipment of this type would be well beyond the scope of even the most enthusiastic of experimenters, devices which use ultrasonic waves to measure distances in air can be very much less complex than one might imagine. Furthermore, they do not require any specialised components and can use ordinary transducers of the type used in ultrasonic remote control and burglar alarm systems.

In this article we will consider a simple system which produces a gate pulse that has a duration which is proportional to the distance to the target object. This is suitable for use in a number of applications, including alarms that operate if a target object is detected within a certain range, or if no target object is detected within a certain range. Ouput circuits for both these purposes are included. It is not difficult to convert the output pulses into either a digital or an analogue distance readout, but these topics will not be considered in detail in the present article. However, a constructional article describing a digital rule with three digit l.e.d. display will follow in a later issue of this magazine.

OPERATING PRINCIPLE

Rather than sending out just a single pulse, most units of this type transmit bursts of several pulses as this generally gives better range and reliability. The basic action of the unit is therefore to transmit a certain number of cycles and then provide a brief pulse to the measurement logic circuit, while the receiver must provide a signal pulse to this circuit when it has received the same number of pulses. The measurement logic circuit must convert these two signals into an output pulse having a duration equal to the time between the two pulses.

The block diagram provided in Fig. 1 shows the general arrangement used in this ultrasonic ranging system. Taking the transmitter first, the basic output signal is generated by a 40kHz oscillator which has its output coupled to a standard ultrasonic transducer. The types normally sold through retail outlets have optimum efficiency at 40kHz, and it is for this reason that an output frequency of 40kHz has been selected.

The oscillator is a gated type, and it is controlled by the output from a simple S/R (set/reset) bistable or flip/flop circuit. The 'set' input of the bistable is fed from a pulse generator which has a low operating frequency of just a few Hertz. When set, the bistable gates the oscillator on, and a series of output pulses are produced. A form of divide by six circuit counts the number of output pulses, and resets the bistable as the sixth pulse commences, giving a burst of what is really five rather than six output pulses. The transmitter thus provides the desired action, with a burst of five output cycles being provided several times per second, and the divide by six circuit giving a brief reset pulse at the end of each signal burst.

In order to achieve reasonable range the receiver requires a large amount of amplification after the receiving transducer. In this case a two stage amplifier is used, with each stage providing over 40dB of voltage gain. In a remote control application ultrasonic transducers normally provide a range of about 13 metres or so, but such a large

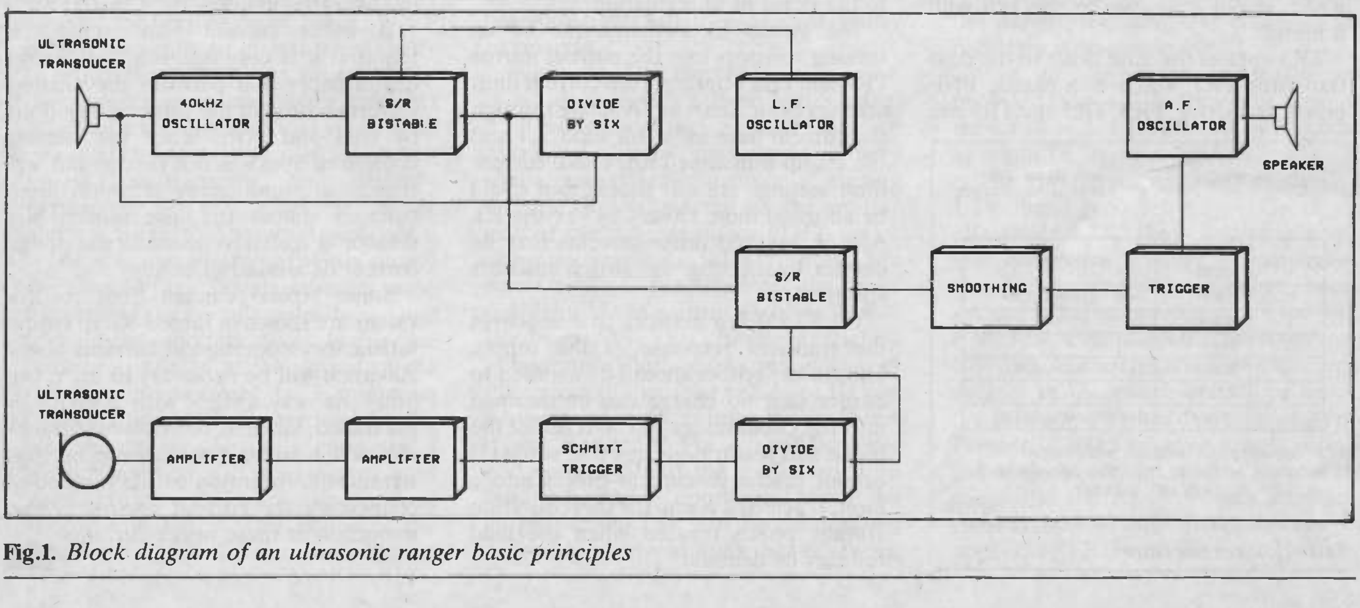


Fig.1. *Block diagram of an ultrasonic ranger basic principles*

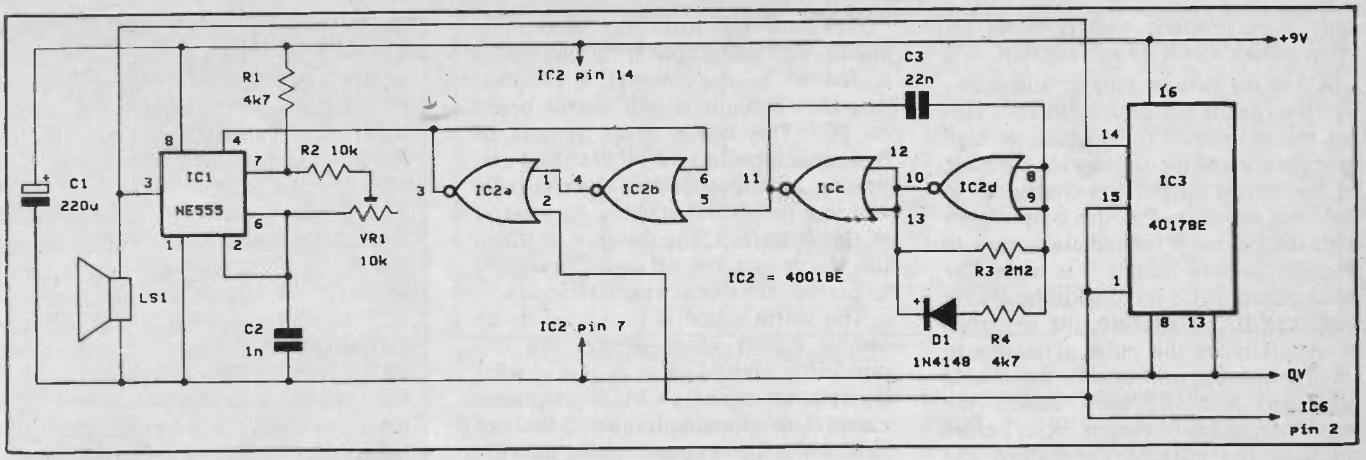


Fig.2. *Ultrasonic ranger transmitter circuit diagram*

range is probably impractical in the present application. One problem is simply that the signal has to travel to the object to be measured, and then back to the unit again, effectively halving the range even if the target object reflects all the received energy back to the ranging unit. Of course, in practice, considerably less than 100 per cent efficiency is obtained, and some objects are considerably better at reflecting ultrasonic soundwaves than others. Optimum range is obtained with something large and flat like a wall or door, and the prototype equipment functioned at a maximum range of around 4 to 5m with obliging objects of this type. Smaller and less co-operative objects will provide a substantially lower maximum range though.

essentially the same as the one in the transmitter, and which therefore provides a reset pulse after each full burst of five cycles has been received from the transmitter.

All that is needed in order to convert the two reset pulses into the required single output pulse is another S/R flip/flop circuit. This is set by the pulse from the transmitter, and reset again by the pulse from the receiver.

There are several ways in which the output pulses can be used, but in this case they are smoothed to provide an output voltage that is proportional to the range of the target object. Remember that the frequency of the pulses is fixed by the low frequency oscillator in the transmitter, and that the duration is proportional to the range of the target

article, and this subject will not be pursued further here. It would be an interesting line to pursue for anyone who would like to experiment with the unit.

With the suggested circuits provided here the output voltage is applied to a trigger circuit which in turn activates an audio alarm generator. Depending on the type of trigger circuit selected, this either causes the alarm to be sounded if the target object is more than a certain distance from the unit, or to be activated if the target object comes within a certain distance of the unit.

TRANSMITTER

Fig. 2 shows the circuit diagram for the transmitter section of the unit. The 40kHz oscillator is a 555 astable (IC1) with the gate signal applied to pin 4.

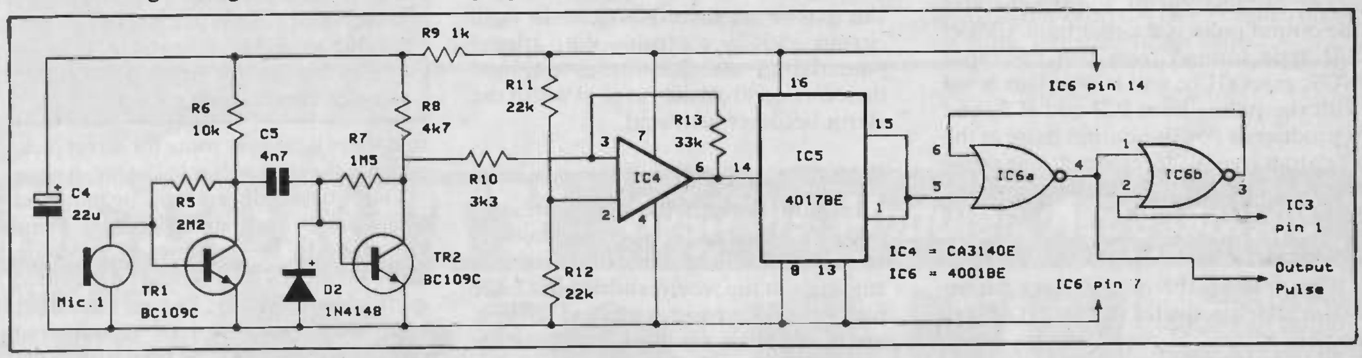


Fig.3. *Ultrasonic ranger receiver circuit diagram*

Although the system may seem to be totally useless, with the weak reflected signal almost certain to be swamped by direct pick-up from one transducer to the other, direct pick-up is not really a major problem. Ultrasonic soundwaves are highly directional, and with the two transducers aimed in the same direction there is remarkably little direct pick-up between them. In fact they can be mounted only 30 or 40mm apart without any problems, and without even having to bother to shield the two units from one another in any way.

The second amplifier stage is followed by a Schmitt trigger circuit which gives a logic compatible output signal. This is fed to a divided by six circuit which is

object. The average output voltage is therefore proportional to the range of the target object, and by smoothing the pulses a d.c. signal equal to the average output voltage is what is obtained.

This output voltage could be used to drive a moving coil meter so as to give an analogue display of distance, but better accuracy and resolution would be obtained using a digital display. It is obviously not difficult to use the output pulse as the gate pulse for a digital counter circuit, and by using the appropriate clock frequency a digital readout in inches or centimetres can be obtained. However, as explained previously, a unit of this type will be featured in a forthcoming constructional

VR1 is used to trim the operating frequency for optimum range.

The bistable is a conventional CMOS type formed from two two-input NOR gates (IC2a and IC2b). The low frequency pulse generator is formed from the other two gates of IC2, which are wired as simple inverters and used in what is almost the standard CMOS astable multivibrator configuration. The circuit only deviates from the standard arrangement in that D1 and R4 have been added to shorten the time for which the output of the circuit is high, so that the output waveform is a series of brief positive pulses rather than an almost squarewave signal. This is important, as the bistable is a simple type which will only work properly with brief set and reset pulses which do not overlap..

IC3 is the divider circuit, and it is a 4017BE one-of-ten decoder circuit. This has ten outputs (0 to 9) which go high in sequence and for one clock cycle each. In this circuit output 5 is connected to the reset input, and as this output goes high the device is immediately reset to the state where output 0 is high. The clock input of IC3 is fed with the 40kHz output of IC1. Therefore, the sequence of events is for the pulse generator to set the bistable and enable the 40kHz oscillator, and IC3 then counts the required number of output cycles before resetting the bistable and halting the output of IC1. The 5 output of IC3 provides the brief output pulse at the end of the signal burst which is needed for timing purposes.

RECEIVER CIRCUIT

The receiver circuit is equally straightforward, and is shown in Fig. 3. The amplifiers are both high gain common emitter types and have capacitive coupling via C5. IC4 is the trigger circuit, and this is a simple operational amplifier type with a small amount of hysteresis provided by R13. The counter circuit is based on IC5, and this is another 4017BE one-of-ten decoder used in precisely the same manner as IC3 in the receiver circuit. It therefore provides a brief pulse at pin 1 each time a full set of pulses has been received.

The bistable circuit which generates the output pulse is another basic CMOS S/R type formed from two two-input NOR gates (IC6a and IC6b). This is fed with the pulses from IC3 and IC5, and it produces a positive output pulse at the Q output (pin 4). If required, a negative output pulse can be obtained from the not Q output at pin 3.

ALARM CIRCUITS

Fig. 4 shows the output stage for an alarm which activates if a target object comes within a preset range. One possible application for a unit of this type is as a parking aid, where it sounds an alarm if a car is taken within a certain distance of (say) the rear wall of a garage.

R14 and C5 form the smoothing circuit, and the output from this circuit is fed to a conventional operational amplifier Schmitt trigger circuit based on IC7. This has a small amount of hysteresis introduced by R17 so that unit triggers to the activated state reliably and in a noise-free manner. As a result of this hysteresis, the distance at which the alarm switches off again is slightly larger than the one at which it triggers.

The alarm signal is generated by an astable circuit which utilizes the two previously unused gates of IC6 in what is a conventional CMOS oscillator circuit. The operating frequency is about 3kHz, which gives good results with the ceramic resonator (LS2) which is driven from the output of the unit. The output tone is reasonably loud, but obviously a more powerful and sophisticted alarm circuit could easily be fitted to the unit if desired.

The oscillator is controlled by a signal applied to one input of IC6d, and the oscillator is enabled when this input is taken low. The Schmitt trigger circuit is a non-inverting type, and it is consequently the range becoming too low that causes its output to trigger to the low state and activate the alarm circuit.

In order to convert the unit to an alarm of the type which is activated if the target object is not within a certain range it is merely necessary to use the slightly revamped arrangement shown in Fig. 5. This only differs from the original in that the Schmitt trigger has been changed to an inverting type. In both circuits VR2 controls the trigger potential of the Schmitt circuit, and therefore controls the range at which the alarm becomes activated.

CONSTRUCTION

In most respects the unit represents few difficulties as far as construction is concerned. One exception is the amplifier in the receiver which has quite high gain, wide bandwidth, and an input and output that are in-phase. These are all ideal for instability due to stray feedback, and the amplifier needs to be sensibly laid out with the input and output well isolated from one another. Obviously the layout should also be such that there is no easy route for direct pick-up from the transmitter to the receiver.

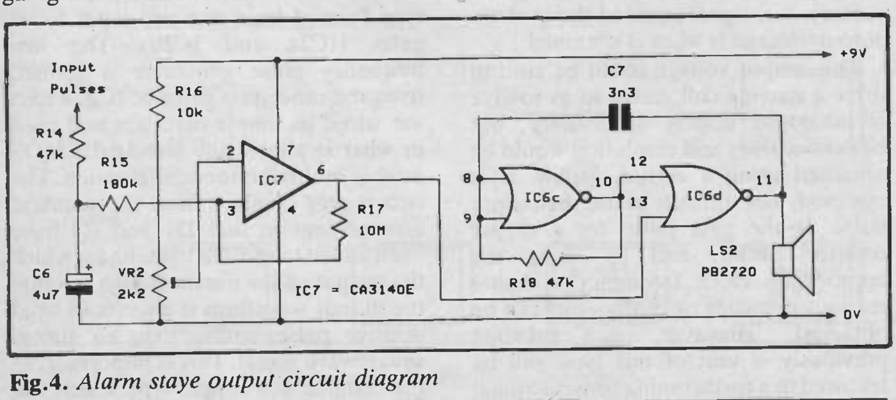


Fig.4. *Alarm staye output circuit diagram*

COMPONENTS . . .

RESISTORS

R1,R4,R8	4k7 (3 off)
R2,R6	10k (2 off)
R3,R5	2M2 (2 off)
R7	1M5
R9	1k
R10	3k3
R11,R12	22k (2 off)
R13	33k

CAPACITORS

C1	220μ 10V elect
C2	1n polyester layer
C3	22n polyester layer
C4	22μ 16V elect
C5	4n7 polyester layer

SEMICONDUCTORS

D1,D2	1N4148 (2 off)
TR1,TR2	BC109C (2 off)
IC1	NE555
IC2,IC6	4001BE (2 off)
IC3,IC5	4017BE (2 off)
IC4	CA3140E

MISCELLANEOUS

Mic.1 and LS1, pair fo 40kHz ultrasonic transducers; 9 volt power source (e.g. PP9); d.i.l. i.c. sockets (1 off 8 pin, 2 off 14 pin, 2 off 16 pin); p.c.b.; wire; etc.

The unit will work with any normal 40kHz ultrasonic transducers, but narrow beam types (such as the TBN40LB from Charland Electronics Ltd., P.O. Box 83, Cobham, Surrey KT11 2QB) are the best type for this application.

This list is for transmitter and receiver circuits only.

The two transducers must be mounted side-by-side and aimed in the same direction. In the interests of precision and consistency they should be mounted quite close together, but on the other hand they should not be mounted so close that direct pick-up from one to the other prevents the unit from working properly. Direct pick-up does not seem to be a major problem though, and 40mm from the centre of one transducer to the centre of the other seems to offer good overall results. The unit should work using any type of 40kHz ultrasonic transducer, although in this application modern highly directional types seem to work better than the older, larger type.

Bear in mind that apart from IC1 all the integrated circuits are MOS types and accordingly require the usual antistatic handling precautions to be observed.

IMPROVEMENTS

The basic circuit works quite well, and there is obviously not vast room for improvement in this area. The obvious thing to try is to use higher gain in the amplifier section, or higher output from the transmitter. Increased gain at the receiver could be ineffective with noise and stability problems unless bandpass filtering was to be incorporated in the circuit. Greater transmitter output power can be obtained by driving the transducer from antiphase outputs, but these must both be low impedance outputs if this system is to be effective. With either increased output or increased gain there will be increased vulnerability to objects in front of the target object (but not necessarily directly in front of it) being detected instead of the desired target. What might be a more worthwhile area for experimentation would be to try increasing the directivity of the transducers with added 'horns' (apparently some bats have horn-like ears and mouths which greatly improve the effectiveness of their echo location systems, and some modern ultrasonic transducers have slightly domed diaphragms which presumably aid directivity and range).

Performance of the two suggested output stages is less impressive, and most applications would require improved alarm generators, and adding one of these does not represent a great technical feat. The response time of the circuits is quite long, due to the necessarily long time constant in the smoothing circuit. A multistage filter would give a faster response time, but a digital solution would probably be better, with (say) the output pulse being compared to a reference pulse from a monostable, and a flip/flop being triggered if the output pulse is shorter (or longer of course, depending on the type of alarm required). This would give a response time that would be mainly limited by the number of tone bursts used per second. This can of course be increased by raising the operating frequency of the L.F. pulse generator, but the gap between signal burst must obviously be long enough for the signal to be reflected back from the target (a maximum of about 30ms, as sound travels at roughly 1m every 3ms at sea level).

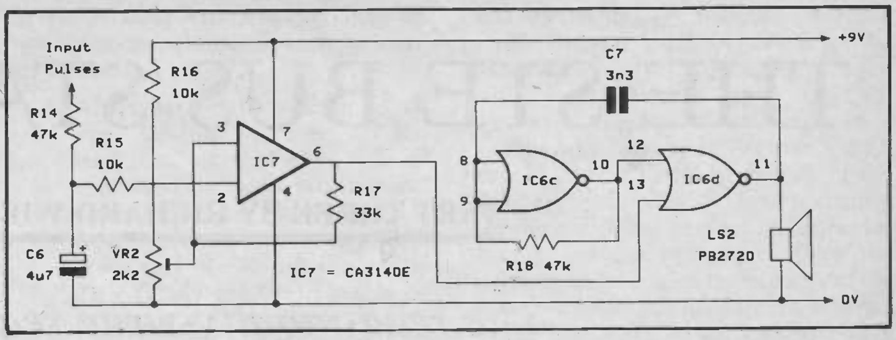


Fig.5. *Alternative triggering arrangement*

There should be plenty to occupy experimentally minded readers with the suggested circuits being used as a basis for the experiments, or if you would prefer a tried and tested constructional project to copy, the digital rule project will follow in a later issue and should fit the bill.

ADJUSTMENT AND USE

The ideal way of adjusting VR1 is to use an oscilloscope or a.c. millivoltmeter to measure the strength of the received signal, and to then simply adjust VR1 for maximum signal strength. This will be much easier if IC2 is temporarily unplugged from the unit and pin 4 of IC1 is tied to the positive supply rail so that a continuous output signal is produced. Also, the unit must be positioned where a reasonably strong (but not excessively strong) signal is reflected back to the receiver. An alternative method of setting up VR1 is to simply use trial and error to find a setting that gives good range.

As explained previously, there will be maximum reflected signal with a large flat object, although this assumes that the aim of the unit is reasonably perpendicular to the object. Irregular shaped objects tend to scatter the signal, while small objects tend to reflect relatively little signal in any direction. Do not expect the unit to read your mind – it will detect the nearest object that reflects a sufficiently large amount of signal, and it is up to you to ensure that this is the intended target object.

THE STE BUS STANDARD

PART THREE BY RICHARD WILCOX

The read-modify-write sequence

The STE Bus is vastly more flexible than any industry standard 8-bit bus previously seen. Using a standard set of 'building blocks', enables all but the most specialised and intractable problems of micro design to be undertaken.

THE Read-Modify-Write (3) Sequence (see Fig. 4). In its basic form covers memory RMW and I/O RMW. It is not to be confused with the read-modify-write operations to be found in the repertoire of most microprocessors. Most microprocessors change or float their address outputs in the middle of such an operation, during the clock cycles in which they operate on the data just read in, before addressing the original location again to return the transformed data. To render this in a form suitable for the STE bus it would be necessary to latch the microprocessor's address outputs during the read part of the operation in order to keep them constant through the modify part. Providing this latching and detecting when it was to be brought into play would be a costly exercise since most microprocessors do not give any unique indication of a r-m-w operation. Even the 'lock' signals of microprocessors designed for multiprocessor applications tend to be asserted during multi-byte instruction fetches, 16-bit loads and stores etc. as well as r-m-w operations. For this reason it is seldom likely to be worth implementing this capability unless your microprocessor is a 'natural' for it. Generally, if default masters are allowed to finish their current instruction before being forced off the bus, there is little call for the form even in systems where bus requests are derived from address decoding, since the single bus request line can be latched from op-code fetch to op-code fetch, thus securing the integrity of all sensitive data manipulations.

The one place where the read-modify-write is useful is when an STE bus interface has to be synthesised using a number of I/O ports belonging to an external computer, in order that the computer may have direct access to STE facilities. Then RMW, when appropriate, simplifies the software used to drive the interface and speeds the proceedings.

Essentially the sequence begins as a conventional read and proceeds thus until DATSTB* returns to the high state. At that point ADSTB* is not allowed to rise and the address lines do not change. t_{CH} = 25 to 45nS should be observed. Neither ADSTB* nor DATSTB* may be tri-stated. Command line CMO changes state to indicate a forthcoming write, the master opens its data bus buffers for output and when all is read DATACK* high, command and data lines stable for at least 35nS DATSTB* may go low and we are into a conventional Write Sequence.

4) The Burst Mode Transfer Sequence. This basic form covers all types of transaction except RMW i.e. it can be a series of reads or a series of writes. All accesses are directed to a single address. Again it is difficult to imagine when it would be worth implementing this capability. It could be used to read a sequence of bytes from a single slave I/O port into memory within the master. However it would again require extensive latching to keep the address presented to bus constant while the incoming data was stowed in the internal memory. The same problems arise when a series of writes is considered. It is clearly intended for exchanges between very specalised logic blocks, not to be used by conventional, microprocessor based masters. It could be used by a synthesised bus interface, to communicate with an STE disc controller, to great advantage in terms of speed and simplicity.

The sequence starts as a conventional Read (or Write) and proceeds thus until DATSTB* returns high, when the address lines, command lines and ADSTB* remain constant. In the case of a series of writes the master's data buffers need not be tri-stated between cycles, a point worth remembering to further simplify the driving of a synthesised bus. Any time after DATACK* has returned high and at least 35nS after the new data is stable in the case of writes, DATSTB* can go low again and a new cycle starts. The final cycle of a series finishes exactly like the corresponding single access. There is no limit set to the number of bus cycles in a series.

THE BUS VECTOR IDEA

We have mentioned the bus vector fetch as a type of read sequence, but not said just what it is for. The idea is that there should be a slave out on the bus whose function is to provide a byte or bytes of vectoring information to a master which has received an attention request signal. The master performs this special form of read with the lowest three address lines set to a binary representation of the number of the attention request that it has received, and the slave responds with the appropriate vectoring information.

There is no corresponding bus vector write, so, if the vector information were to be changeable by software during an application's initialisation sequence, the vector slave would have to respond to say a block of I/O addresses. This dual addressing would make for a very complicated bus interface. If the vectoring were to be shared out amongst the I/O Slaves, turning each into a sort of super Z80 support device, the problem would be multiplied since the vector number that it responded to would also have to be user programmable.

Sensibly it is specified that any master which is capable of vectoring by this means should also be capable of polling I/O slaves and/or using an internal vectoring system.

THE STE SYSTEM ELECTRICAL AND MECHANICAL SPECIFICATION

1) The Backplane. The STE backplane is a standard height to fit the 3U high version of the 19-inch rack system. This same height is used even if double eurocard sized boards are employed. The

STE backplane is then fitted at the bottom of the back of a 6U high 19-inch rack. This leaves the top half of the back edge of the double eurocard available to bring I/O connections out at the back of the rack, and makes the system much tidier in use. The recommended inter-connector spacing along the backplane is 0.8 inches from centre to centre. The only other spacing that is allowed is 0.6 inches centre to centre for backplanes bearing not more than fourteen connectors. The recommended spacing allows a maximum of 21 boards to be accommodated within a 19-inch rack.

The backplane is to be designed, using transmission line principles, to have the following characteristics:

(a) Maximum signal path length 500mm
(b) Characteristic resistance 60Ω +/−5%, including connectors, but unloaded
(c) Constant width signal tracks to keep this characteristic resistance constant as 'seen' from each connector and homogenous throughout
(d) A ground plane on the component (connector) side of the board which is continuous except for holes allowing individual connector pins to pass through the board without shorting, i.e. the holes in the copper groundplane should be slightly larger than the drilled holes for the connector pins. Slot shaped holes in the copper groundplane surrounding a number of pin holes are not allowed.
(e) The ground plane should be connected through the board to the 0v supply tracks and to the signal return/guard tracks at each connector station.
(f) Signal tracks shall have an overall resistance, end to end, of less than 1Ω when a DC voltage is applied.
(g) Power supply tracks shall have a DC resistance of not more than 5mΩ from the connection point to the relevant pins of any connector.

2) The Termination Networks. There are two options, active and passive termination.

(i) Active termination: Each signal line, i.e. all bus lines on the backplane except +5V, 0V, +/−12V and the signal return/guard tracks, must be connected to a 2.8V, regulated supply via a 270Ω resistor of +/−2% tolerance. The 2.8V supply must be capable of supplying a 0.5A current to each such set of resistors within a voltage tolerance of +/−5%.
(ii) Passive termination: Each signal line as defined above must be connected to the +5V supply by a 470Ω +/−2% resistor and to 0V by two 1k2 +/2% resistors in parallel.

In addition to these 'biasing' arrangements for all signal lines, ADSTB*, DATSTB*, DATACK* and SYSCLK should be 'diode clamped' to minimise the extent to which they undershoot logic low on a negative transition. A suitable circuit for this purpose is seen in Fig. 5.

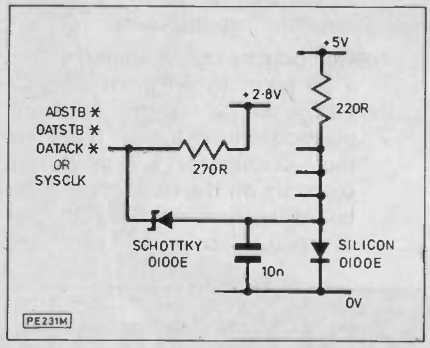


Fig.5. *Diode clamp for strobe and clock lines*

On backplanes with five or less connector stations, a single termination network attached within 20mm of one end of the bus lines, and a single set of clamping diodes at the same point, is sufficient. For backplanes with more than five connector stations, two complete termination/clamp networks are required, connected one at either end of the bus. In the case of active termination a total of 1A must be available from the 2.8V supply.

3) Power Supplies. Each board in a system may draw up to 4A from the 5V supply and up to 1A from each of the auxiliary supplies. These figures, together with the number of connector stations on the backplane, allow the designer to determine the capacity of the power supplies required by the system.

The tolerances on the various supply voltages are as follows:

+5V	(V_{CC})	+5%, −2.5%
+12V	(AUX+)	+/−5%
−12V	(AUX−)	+/−5%

For all these supplies, ripple at frequencies below 10MHz should not exceed 50mV peak-to-peak. These parameters should be checked for a range of conditions from no load on any socket to full permitted load on all sockets, when setting up a power supply module.

4) Suitable Bus Drivers and Bus Signal Receivers. All bus drivers employed in STE systems, whether tri-state, totem-pole or open collector, (see Fig. 1 for specific line requirements), must be capable of sinking 24mA at a V_{OL} of 0.5V and in the cases of tri-state and totem-pole output buffers must be capable of sourcing 6mA at a V_{OH} of 2.4V. This is a series restriction and in effect rules out all LSTTL, totem-pole output, standard gates *and* high drive buffer/interface gates. Totem-pole outputs to the bus have to be achieved by using permanently enabled tri-state buffers. Amongst LSTTL tri-state buffers themselves, only a small range of types may be used. These are the 74LS240, 241, 242, 243, 244, 245, 540 and 541. No other 74LS type numbers appear to have a sufficient current sourcing capability. Problems will inevitably arise in designing with this limited range of buffers since smallest number of outputs that can be enabled or disabled together is four when using the 74LS240, 241, 242, 243 and 244, or eight when using the 74LS245, 540 and

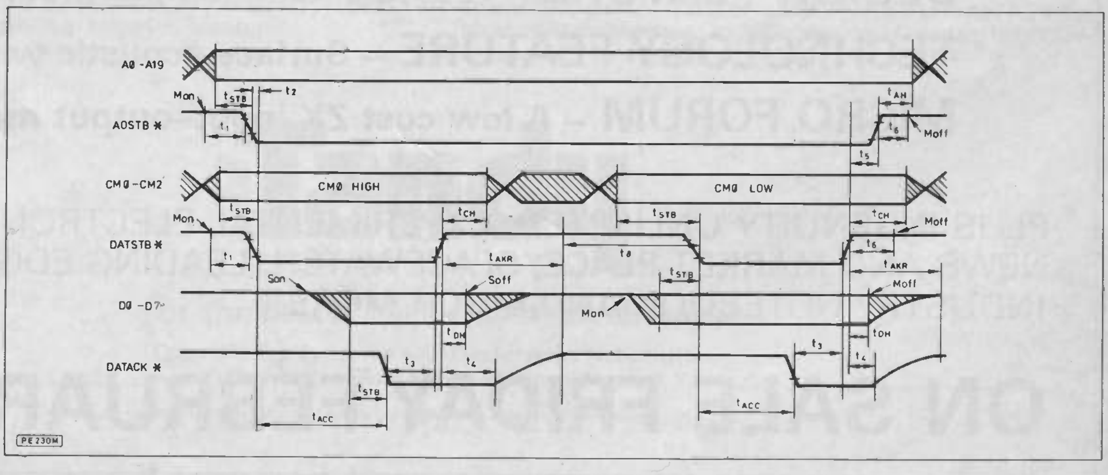


Fig.4. *The Read-Modify-Write sequence timing diagrams showing all the main signal lines*

541. A good ploy on a master board is to use a block of four buffer outputs thus: two drive DASTB* and ADSTB* and the other two receive DATACK* and TFRERR*, which are not required when the master is not in control of the bus or during parts of a period of bus control when it is convenient or necessary to tri-state the master's own strobes. The three pseudo-totempole outputs, using permanently enabled tri-state buffers, SYSCLK, BUSAK1* and BUSAK2*, can easily be grouped together if the system controller and the bus arbiter share a board.

There is a requirement that inactive outputs, tri-state off or open collector off, should have a maximum leakage current onto the bus lines of 50μA with the bus at high level and 100μA with the bus at low level. This rules out the use of any LSTTL open collector buffer as those with a high enough sink current capacity have leakages of up to 250μA. Discrete NPN transistors should be used to provide a final inverting open collector stage for such signals. The current limiting resistor between the last gate output of i.c. logic and the base of the transistor should be of such a value as to allow a collector current of 24mA to flow through the transistor when the signal is active.

Bus receivers must react to a voltage of 2.0V or higher as a logic high and to voltage of 0.8V or lower as a logic low. Receivers connected to the ADSTB*, DATSTB*, DATACK* and SYSCLK lines must further have Schmitt-trigger action. Schmitt-trigger action is desirable for all receivers, though not mandatory. Any of the drivers mentioned above can be used as receivers and, in addition, the 74LS13, 14, 132, 273, 373, 374, 521, 533 and 688 all have the Schmitt-trigger characteristic. Virtually any LSTTL part may be used as a receiver, if it is decided not to provide the Schmitt-trigger action on lines where it is not mandatory.

5) Restrictions Affecting Board Design. In addition to the overall current consumption restrictions mentioned above, individual board designs are subject to a number of dimensional and lay-out restrictions:

(a) Board thickness within 2.5mm of top and bottom edges: 1.6mm. This is to ensure that the board will fit standard guide rails. In addition the area of board under the connector must be shaped or of such a thickness as to ensure that the connector is properly aligned, in the case of a board of non-uniform thickness.

(b) Component layout should follow a 36 point by 60 point 0.1 inch grid, on a single eurocard, positioned in such a way that when the connector is positioned correctly on the back edge of the board the first and third columns of points coincide with the connectors solder pins. The grid should be symmetrically placed about the long axis of the board as should be the connector.

(c) For double-sided p.c.b. material the maximum length of the p.c.b. traces for the ADSTB*, DATSTB* and DATACK* signals should be 50mm measured from the driver output to the connector solder pin.

(d) The maximum capacitance that any board traces and input or output can present to the bus line to which it is connected is 20pF. Allow 5pF for the i.c. input or output (TTL) and 3pF per inch for fine traces and it should come out within the limit.

CONCLUSION

And there you have it. STE is vastly more flexible than any previous bus for 8 bit micros. The facilities that it provides and the methods that it prescribes enable all but the most specialised and intractable problems of micro system design to be undertaken using a standard set of building blocks, which can be fitted together with a very high chance of immediate success on the hardware front. Software will always take time and cost money, but the STE concept gives the system designer access to all the stored up wealth of applications programming that has been accumulating on 8 bit micros over the last decade and a half. PE

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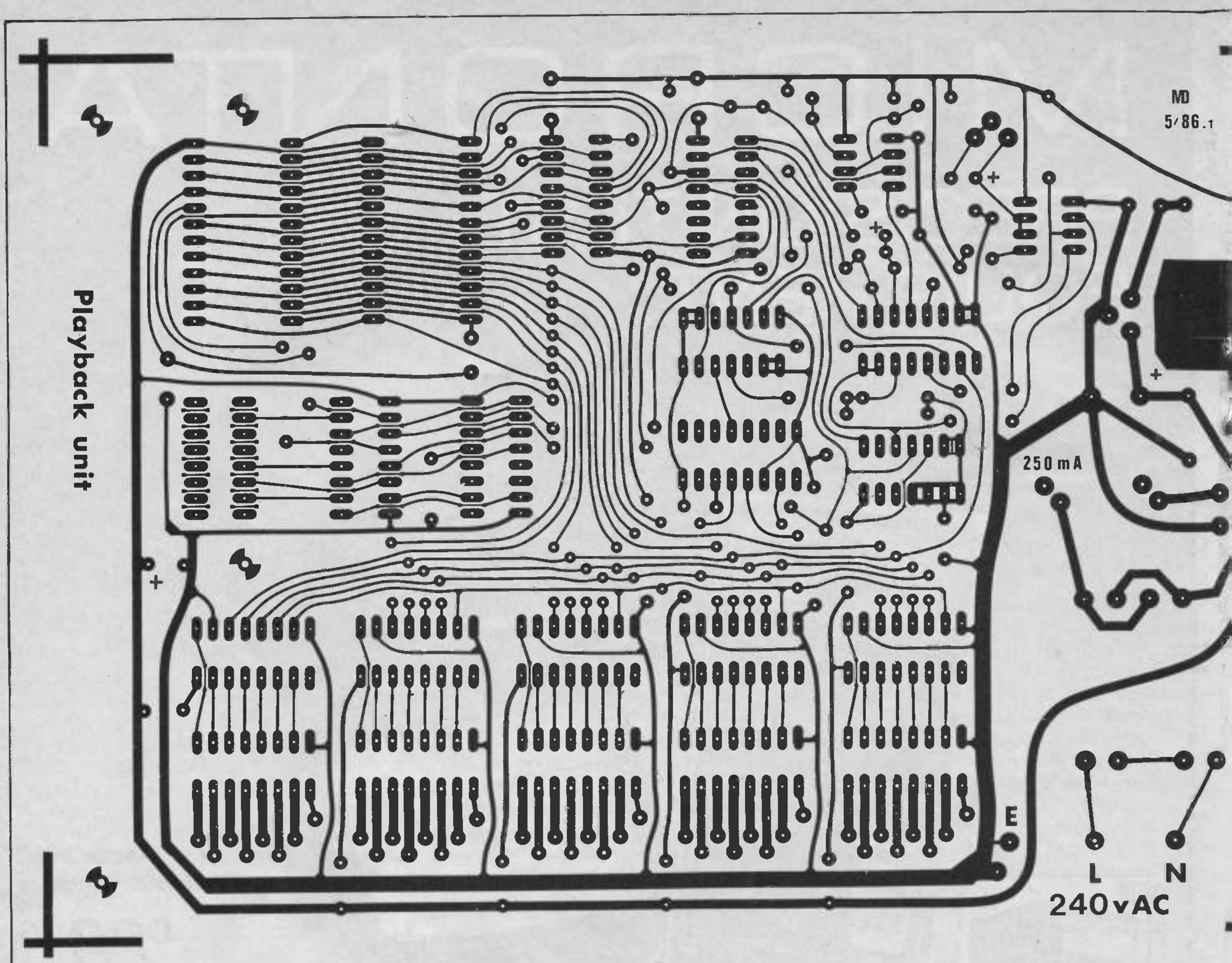

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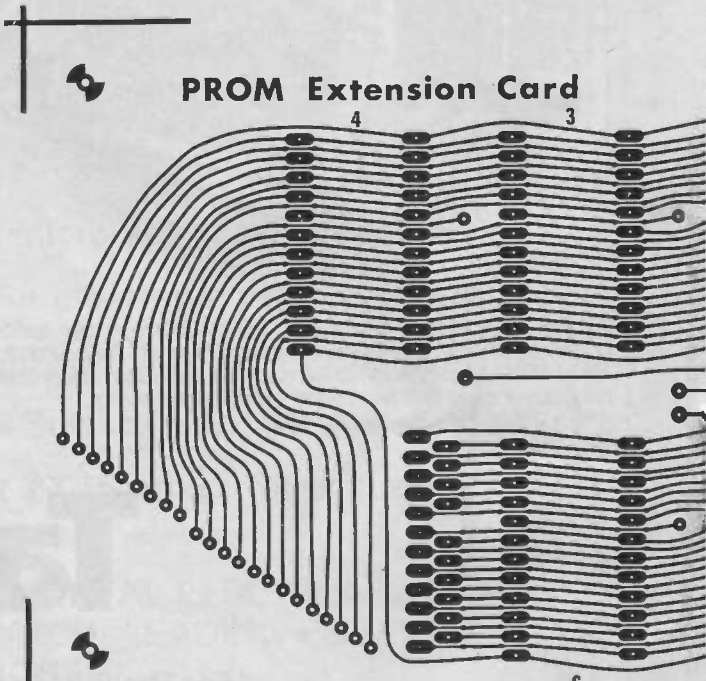

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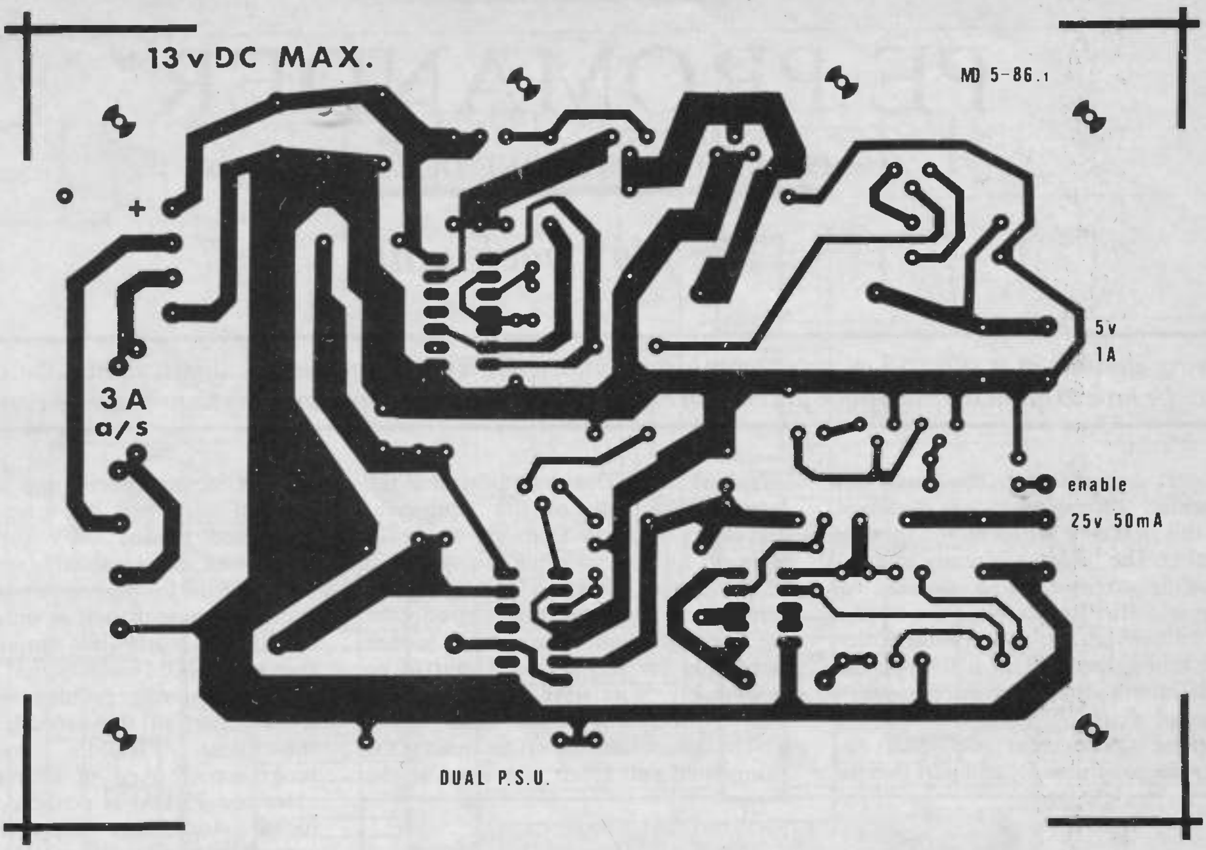
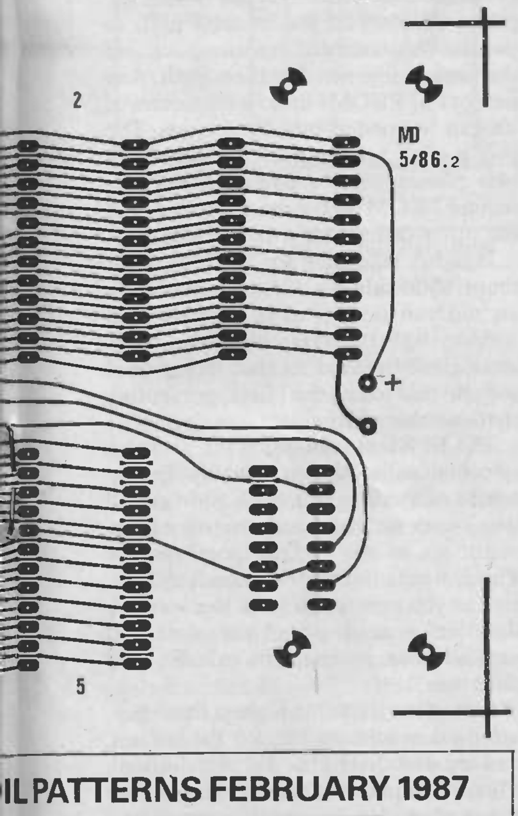
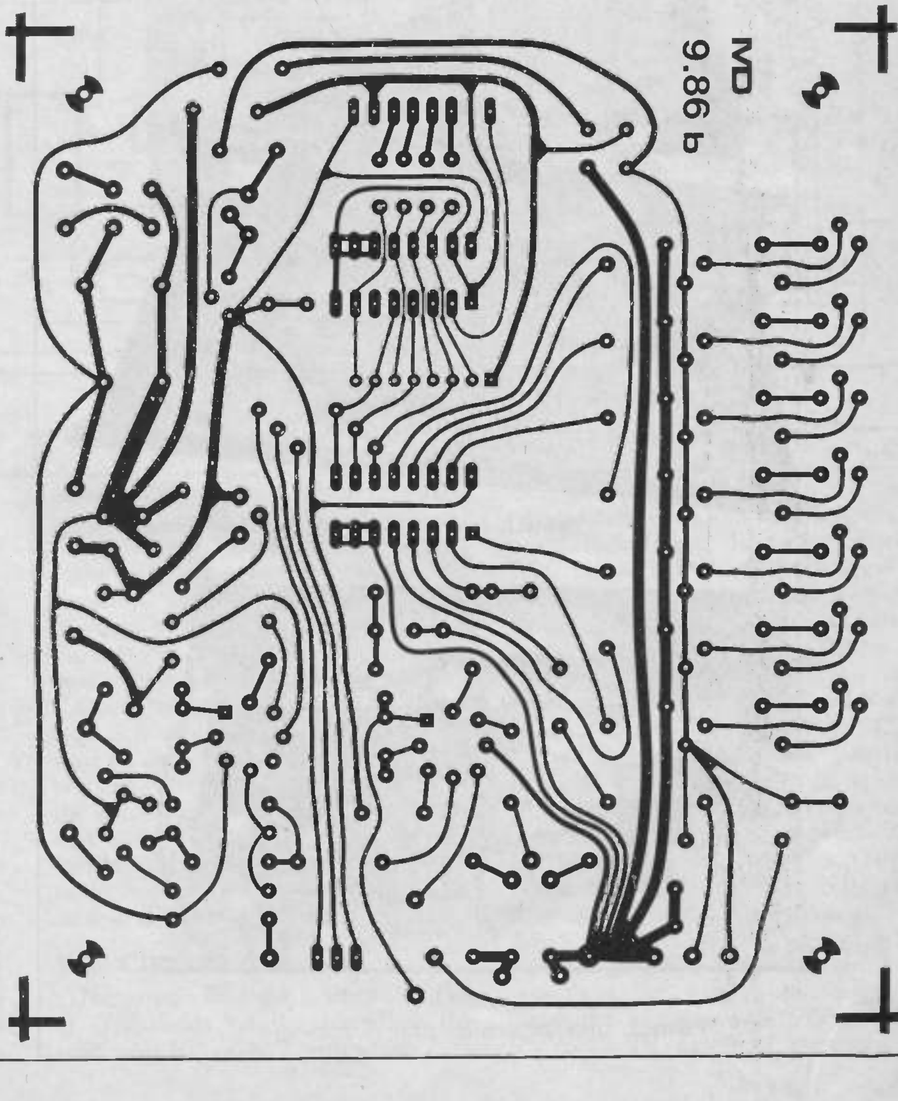


←PE133	PE130 ↑
↓ PE131	PE132→





OIL PATTERNS FEBRUARY 1987

PE PROMANDER

PART THREE BY MIKE DELANEY

The play back unit

Having arrived at a method of producing programmed EPROMS for display applications, we can now describe how to build the play-back unit which once again requires no programming knowledge or computer.

In part one and two the basic idea behind 'Promenader' was discussed, and this part now brings all the theories together. The pudding is ready to eat!

Having arrived at a handful of programmed PROMs, we now need a unit to convert the digital information back into a display. This is the purpose of this month's feature. During the early stages of design, I decided to split the complete system into two, part one being the *programmer,* and part two the *playback unit.* This was to reduce the weight and bulk of the equipment necessary to carry from gig to gig. A spin-off for anyone using the system in a permanent set-up is the ability to program at leisure, transferring only the 2532s from home to venue. By further arranging for the playback unit to be reasonably accessible, changing the lighting became a simple affair.

The exact means of mounting the completed unit is left very much to the reader's requirements and ingenuity. Bear in mind that the main p.c.b. is connected to the 240V supply, and ensure that access is suitably restricted.

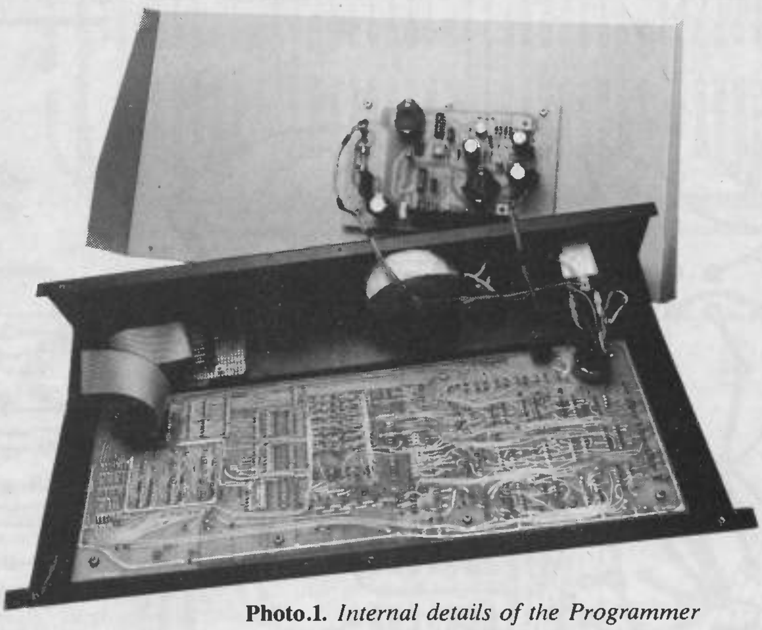


Photo.1. *Internal details of the Programmer*

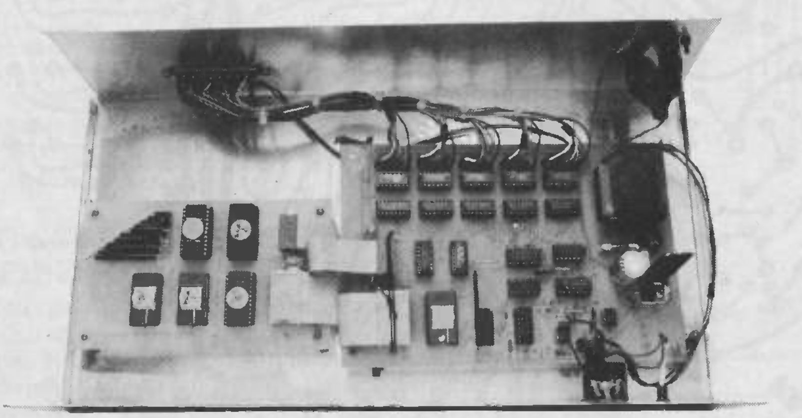


Photo.2. *Internal details of the display unit*

During the first test run it immediately became apparent that, in order to give a display of worthwhile duration, more than one PROM was required. This now brought in another problem: what to do if only part of the second, and any subsequent PROMS, has been programmed? And of course, if one extension PROM is possible, why not more? And what happens if any extension board is not completely filled with memory? Clearly, it is not acceptable to have long chunks of blackness while the system sorts itself out. The change-over time between memory chips must be as fast as possible, within reason, and any blank (unprogrammed) areas of memory must be skipped over.

These two requirements were the prime deciders of the method used to decode the recorded information, and the final design satisfies them both. Any number of PROMs up to a maximum of six can be loaded into the boards. The two p.c.b.s are connected together by two ribbon cables, one replacing the second PROM on the master board, and the other fitting into a 16-pin socket.

It didn't take long for us to discover that ribbon cables and transportation in an old van do not mix! Mod. no 123 coming up! Both p.c.b.s have holes strategically placed so that lacing cord may be tied round the plugs, preventing them working loose.

The EPROM containing the program information is shown roughly in the centre of the diagram, with address and data buses on either side, much as you might see in any PROM-based system. This is where the similarity ends though, for, as you will recall from the way the data bus is made up of part data and part address, it cannot be called a true data bus.

Part of the data, the highest three bits, are used as address bits for the latches, and are decoded by the decimal decoder. This information is used either to fire the monostable, giving a pause so the display can be seen, or fire the bistable

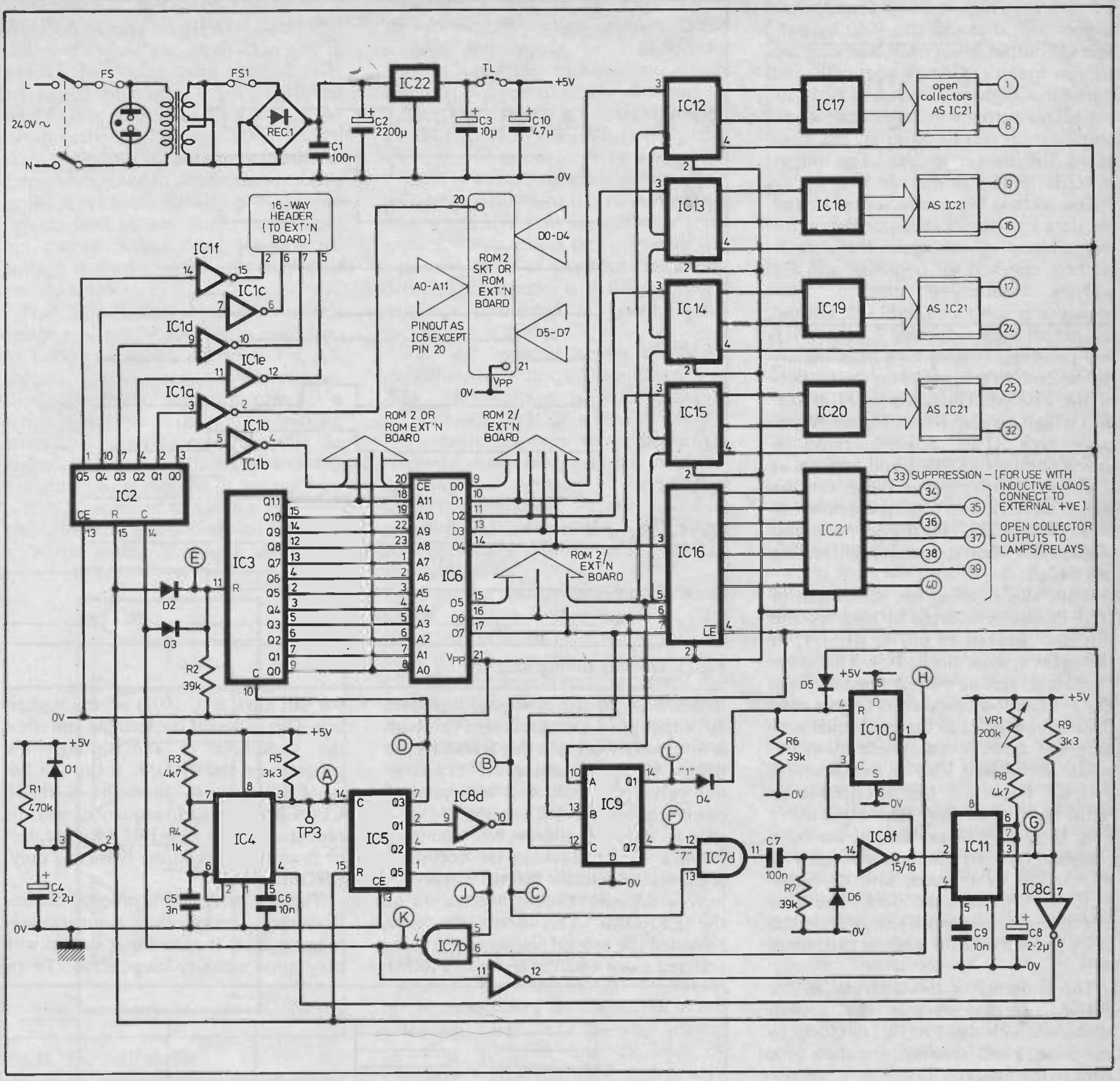


Fig.10. *Display unit circuit diagram*

and enable a different PROM in the sequence.

The EPROM is clocked by the address counter, a 4040, 2^{14} binary divider. This is a ripple counter, i.e. the clocking action ripples through in a slow (digitally slow, that is) progression. This is fine, as long as enough time is allowed for the sequence to finish and the address bus to settle before actually attempting to *use* the bus.

Since one of the prime concerns in this system is timing, things must always happen in the right sequence. This allows the use of a sequencer as an elegant solution. Sequencer 1, in this case. Clock pulses at about 40kHz are fed to sequencer 1, and this steps round at one tenth of that frequency. Sequencer 1 does most of the housekeeping, and the system is guaranteed always to remain synchronised, despite having counters which take a week to settle and monostables with a variable mark-space!

By simply arranging a second sequencer, sequencer 2, clocked by sequencer 1 *and* the bistable, we can use the data bus to clock automatically to the next PROM, and the timing is locked neatly together.

Once the data is latched into the latches it may be considered as steady-state so far as synchronising with zero-crossing, etc. is concerned. It was for the sake of maximum system flexibility that latches are fitted in this position. Synchronisation to the mains would have been much more difficult to achieve if the outputs had been strobed.

THE CIRCUIT

The circuit diagram is shown in Fig. 11. The heart of the circuit is the sequencer IC5, a 4017, with which I am sure any enthusiast is likely to be well-acquainted. Only four of its outputs are used. Referring to the timing pulses in Fig. 12 will help to understand exactly how they are used. At the start of a sequence of loading seven bytes into the latches, IC5 is clocked by IC4, a 555 timer. The address counter is at address 000, and the data at this address is present at each of the latches , IC12–16, on pin 3. Q1 of the sequencer goes high, and this is inverted by gate 8d, latching the data through to the outputs of the latches, appearing on pin 10 of the 4099s.

Having stored the first byte, Q1 goes low, and Q2 goes high. This in effect asks the AND gate, 7d, whether a '7' (BINARY 111), is now present at the three highest bits of the data bus. Since this was the first in this particular sequence, the answer is 'NO', (actually '1' (001)). The output of 7d remains low.

Q3 now goes high in its turn, and when it goes low, it clocks the 4040 by one. The Q4 output is not used, allowing the address to settle. Q5 now goes high, and tests for a high on the output of IC10, pin 1. This output will have been set low on power-up, via its R input, pin 4, so again, the answer is 'NO'. The output of IC7b, pin 4 also remains low.

The address bus is now set to '1', and the data bus carries the information for this address. Once again the data is latched, checked for contents, and the address counter is clocked. This sequence is continued until D5, D6 and D7 are all high – decimal 7, binary 111. IC9 pin 4, 'Q7', goes high immediately the seventh byte appears on the outputs of the PROM. Thus, when Q2 of IC5 puts a high on gate 7d pin 13, the output goes high. This positive pulse is differentiated by C7/R7, and appears as a short negative-going pulse on the trigger of IC11, which starts the time-out pulse on this 555. This trigger pulse also clocks IC10 when it returns high, setting pin 1 high.

While this is going on, the output of IC11 has been inverted by gate 8c, and this low is taken to pin 4, RESET, of the main system clock, IC4. This stops the clock, and its output remains high. The system now twiddles its fingers until the mono decides to flip back. Just how long this takes is dependent upon the value of R8 and VR1 in combination with C8. For relays, this will need to be fairly long, since they take a relatively long time to pull in. C8 should be a tantalum type, to minimise leakage. The mono flips over again, into its stable state, and releases the clock. The next negative-going edge on the address bus clock pin will take the address to decimal '8'.

The contents of this address on the PROM decide whether the system continues with this PROM, or clocks to the next. I will take the situation of a continuing program first.

At the recording stage we know that directly after a '7' comes a '1' on the highest three bits of the data byte. Using this '1', after it has been decoded by IC9, pin 14, to RESET the bistable, IC10, which the '7' has just SET, ensures that when Q5 of the sequencer goes high, the output of gate 7b remains low, and the sequence of events will continue as before.

Let us now look at the sequence when one '7' is followed directly by a second '7', as would happen when the program comes to an end.

The first '7' will have toggled over the bistable, so pin 1 will be high. Q3 of the sequencer now clocks the 4040, and, because the program is at an end, the highest bits of the byte remain high, since there is nothing to pull them low – another '7'.

Pin 14 of IC9 remains low, so the Q output, pin 1 of the bistable stays high.

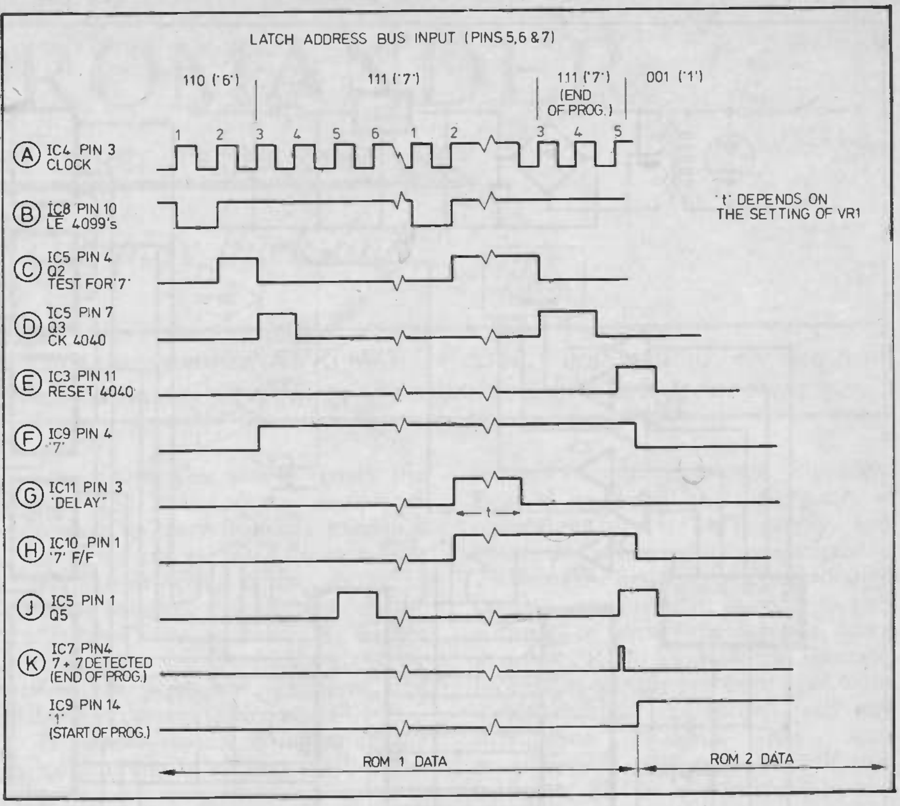


Fig.11. *Display timing diagram*

When Q5 of IC5 now goes high gate 7b output pin 4 also goes high. This high is inverted by 8e, and this RESETS the mono, IC11, preventing another time-out period. 7b output is also used to clock sequencer 2, IC2, and at the same time to reset the address bus counter.

Once again, recalling the recording sequence, at address 000 we will *always* have a decimal '1' programmed on all the EPROMs. This being the case, provided the second sequencer has now selected a slot wherein resides a PROM, we will have a '1' (001) on the highest bits. This will reset the bistable and allow the sequencer to run through the program on the PROM. If the slot has no PROM in it, then the LATCH-CLOCK-SEARCH sequence will be repeated until a new PROM is located, or it arrives back at the first (and only) PROM.

This is a fairly simple process, the one drawback being the comparatively lengthy delay incurred in a system with only one memory chip fitted. To be

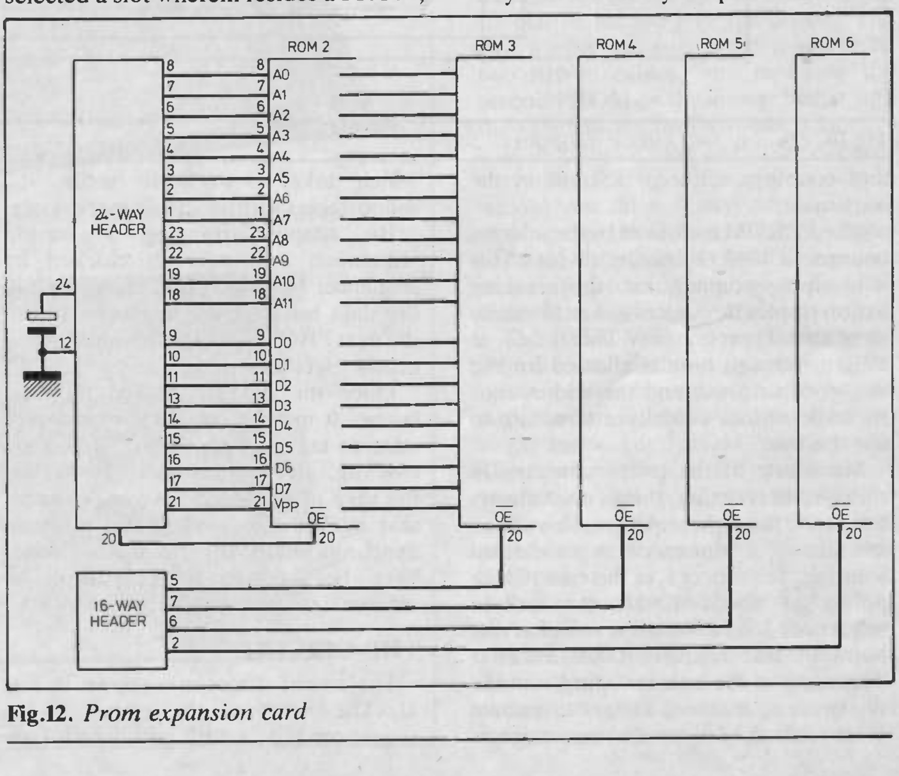


Fig.12. *Prom expansion card*

honest though, the system as it stands is designed around six EPROMs, so that situation should not arise. One way in which the delay can be visually minimised when using between two and six PROMs is to space them out in the two boards, say in every other socket. Data present on the outputs of the driver chips can be used to drive either resistive or inductive loads directly, provided the current sunk by any single output does not exceed 500mA, and the external voltage applied to any of the outputs is less than 40V.

The 2003 buffer chips used in this design may not be familiar to everyone, so I have included a pinout, Fig. 13. These chips are open-collector Darlington pairs, and each pair has a series resistor on-chip, making interfacing easy. This, combined with the suppression diodes, offers a very useful, if slightly costly method of output.

If it is intended to use the playback unit to control mains-powered lamps, it is worth noting a couple of points.

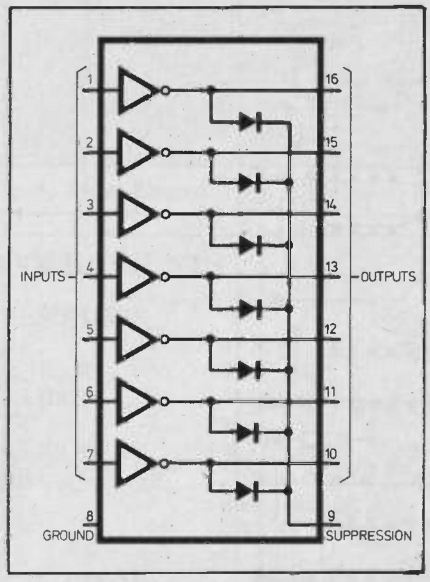


Fig.13. *The 2001 buffer*

Driving 35 mains bulbs, each rated at, say, 100 watts, requires an awful lot of power. Do your sums . . .! Make absolutely certain that all wiring, plugs, sockets and whatever are suitably rated. I would certainly not recommend using much above the 25W pygmy bulbs, and even then, 35 × 25 = 875 Watts!

Now, unless you want the C.E.G.B. down on you like a ton of bricks, you *must* synchronise the firing point of the bulbs to the zero-crossing point of the mains. Failure to do so, particularly when using triacs or s.c.r.s as the switching elements, will cause a very great deal of mains-borne interference. Don't forget, when calculating currents for any type of 'bulb', that the cold resistance is a lot lower than the hot, so allowance must be made for cold inrush current.

Probably the safest way of driving a bulb, unless you are confident of what you are doing, is to stick to a transformed, low-voltage system. Quite a good display can be obtained by making multiple colour, multi-bulb displays, using mini wire-ended bulbs.

The power supply is a straightforward affair. The supply is switched by the speed pot, so this needs to be a two-pole type. It is worth fitting a neon indicator on the front panel, as this can save some time when trying to fault-find a 'dead' system. The p.c.b. is provided with the necessary space to accommodate a 6VA 0–6, 0–6 transformer with the secondary windings connected in parallel, and rectified by a bridge.

The d.c. present across the main smoothing capacitor, C2 should be about 8.2V. This voltage is regulated and reduced to 5V by IC22, a 7805. C3 should be a tantalum type to improve h.f. response. A test loop has been included, enabling the regulator to be isolated from the remainder of the circuit if required. This enables the circuit to be debugged without the danger of blowing the PROM.

As can be seen from the component layout detail, a further capacitor, C10, has been included near to the PROM sockets. This is required to reduce the effects of the drivers sucking current and putting noise onto the supply line, so should not be forgotten. Outputs from the second sequencer, IC2, are inverted by IC1 before being taken to the 16-pin header socket. This feeds the extension PROM card with $\overline{OE}$ inputs to the memory chips, and is connected to the card by a 16-way ribbon. The address and data lines are interconnected by a 24-way ribbon which replaces PROM 2 in the main board.

THE PROM CARD

Outputs from the PROM 2 position on the main board are connected to the extension card via a 24-way header, including the +5V and 0V lines. A capacitor, C11, is included to decouple the supply. Should it be necessary to make the inter-board distance more than a few inches it would be advisable to replace the power connections with a slightly thicker grade of wire. The $\overline{\text{PROM ENABLE}}$ lines are connected to the extension card via a 16-way header. In this way the system addresses each PROM in turn, and each one outputs its data onto the data bus.

If, during test, it is necessary to unplug the 24-way header, it will probably be as well to remove the 16-way also. If it should be left plugged in, the PROMs on the extension would have voltage levels applied to their $\overline{\text{ENABLE}}$ lines, with nothing on the supply lines. This could possibly damage their internal structure.

CONSTRUCTION

Quite a few wire links are required. This approach was used instead of a

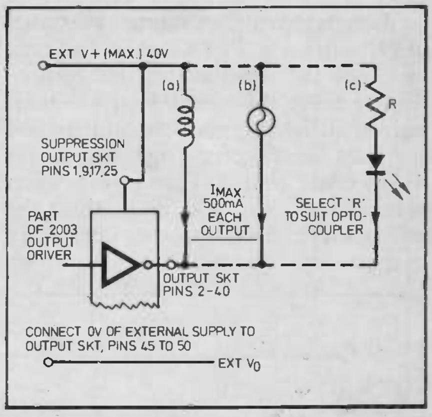


Fig.14. *Details for high current output*

double-sided board, to minimise cost, but I certainly would agree that they are an irksome chore. Fit them first, and get them out of the way.

Building up through the heights of the components, starting with diodes, going on to resistors, and so on is probably the most satisfactory method of assembly. Check the polarity of the capacitors before and after 'glueing' them in. Tantalum caps take on the appearance of a dried current when abused and they also let out quite a bit of smoke, which I am told is toxic! When fitting the regulator, use a liberal amount of heat-sink compound. No insulator is required, and this helps thermal conduction. The heat-sink is a home-made affair, a piece of 18swg (fairly thin, for those of you used to thinking in metric) ally sheet with a hole in one end for the fixing bolt, a righ-angle bend, and a matt black coating. This should not get hot to the touch; if it does, there is something wrong. A test loop has been included which enables the 5 volt line to be isolated to assist with fault diagnosis.

Before fitting any i.c.s, the 5V line should be checked, first with the test loop open, and then with it in place. Refer to the layout while fitting the i.c.s. once you are satisfied the supply is correct. For the first checks it is not necessary to fit more than one PROM.

It may be as well to offer up the completed board to the case, and determine the length of flying leads required to connect to the output socket. Fitting this wiring and the socket at this stage will make testing easier, particularly if using a similar method of test display as used by the author (see photo). The type of socket is unimportant, just make sure it can handle the current. The author used a 50-way D type, which are available from a number of sources. Use any spare connections in the plug for the low-volt return. These should be connected to the p.c.b. at the terminal adjacent to IC17.

When a 50-way socket is used, this will allow ten inputs to be connected in this way.

To assist with fault finding I have included oscilloscopes A to L from strategic positions throughout the board.

There is also a 'TEST' prom available, along with some 'PROGRAM' PROMs, so check the small ads in this edition. The test PROM is designed to check individual light outputs, the columns and the lines, and is pretty mundane as far as disco use goes. Do not forget, when testing the playback unit, that the outputs are open-collector. They are current-sink devices: they have no means of sourcing current. Therefore an external power source is needed, and it must be connected so that the collectors of the outputs see a voltage higher than the low return. This sounds obvious, but it is just the sort of thing which is easily overlooked, and it takes a few hours to find!

In use, it has been found very useful to have the LED board testpiece on hand. It comes into its own when trying to discover whether the cause of a non-working lamp is the bulb or the driver. Replacing the lamps with the l.e.d.s soon shows where the problem lies.

Although there is no setting up to do, you may wish to do the maximum or minimum time-out periods of IC11. R8 and C8 can be altered within reason to suit individual taste or need. The master

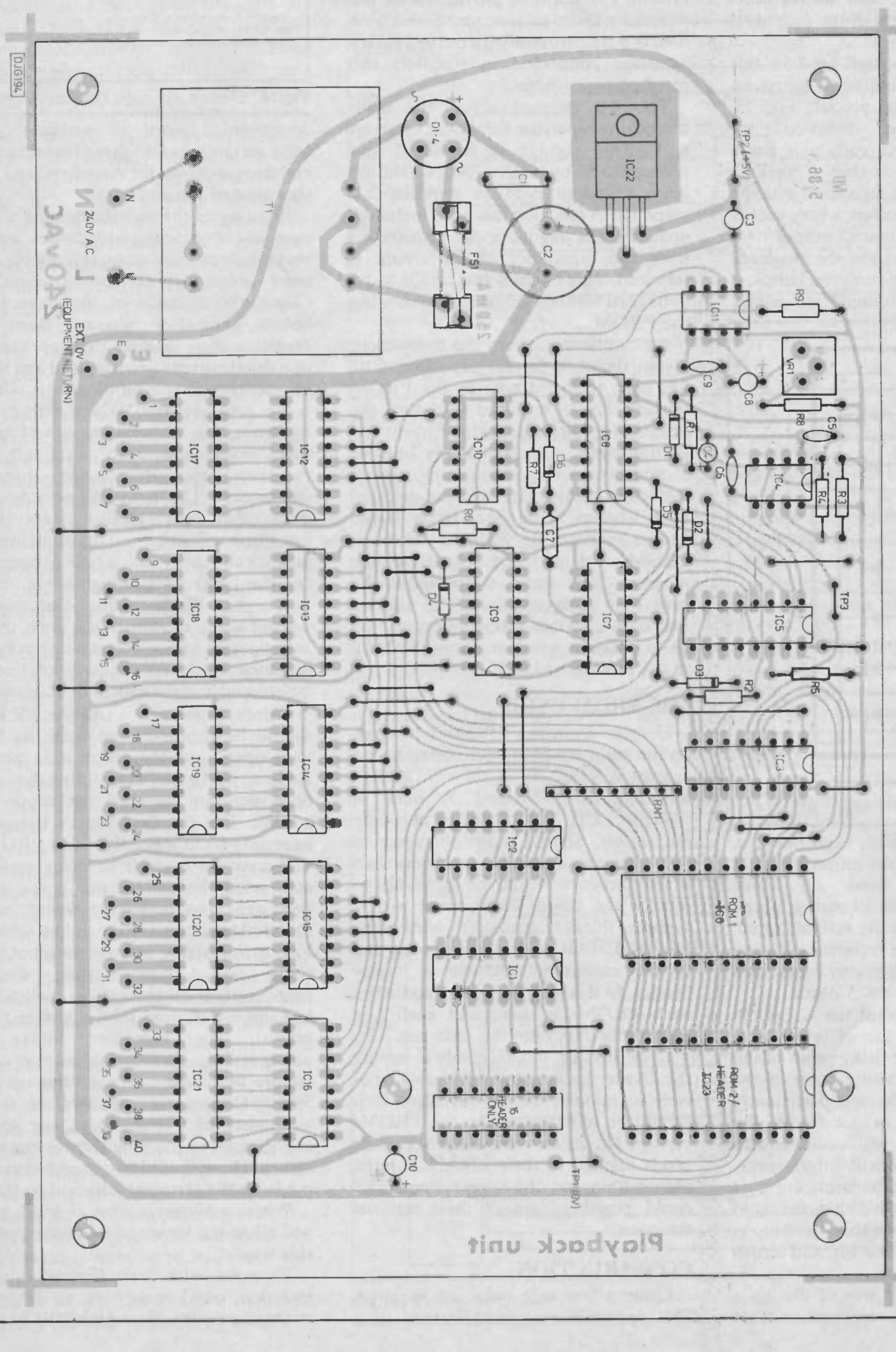


Fig.15. *Playback p.c.b. details*

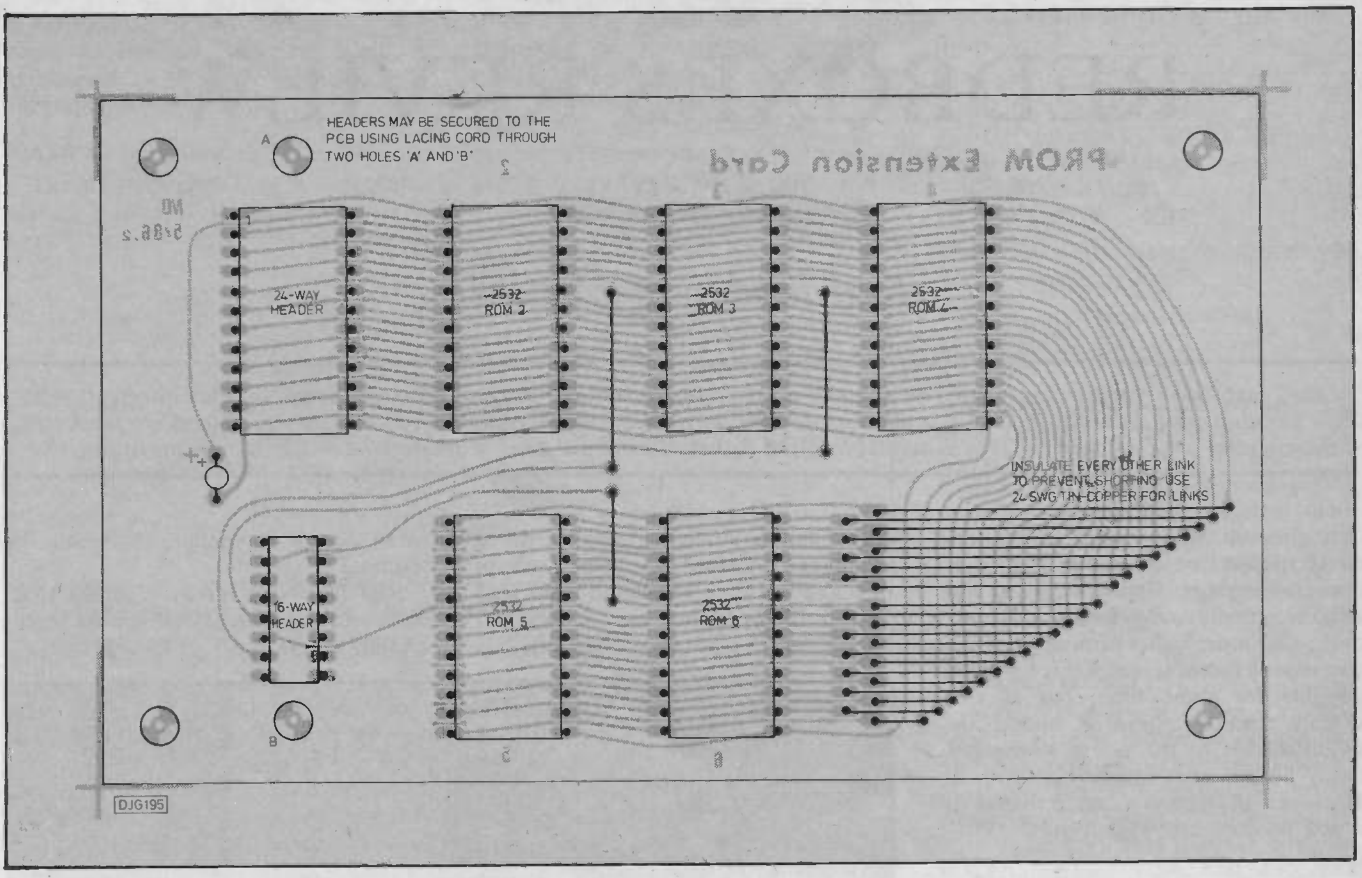


Fig.16. *Prom Extension p.c.b. details*

COMPONENTS . . .

RESISTORS

R1	470k
R2,R6,R7	39k (3 off)
R3,R8	4k7 (2 off)
R4	1k
R5,R9	3k3 (2 off)
VR1	250k lin. with d.p. mains switch
RN1	10k x 8 s.i.l.

CAPACITORS

C1,C7	100n disc ceramic (2 off)
C2	2200µ 16V elect
C3	10µ 16V tant
C4,C8	2µ 16V (2 off)
C5	0.3n3 disc
C6,C9	10n disc (2 off)
C10	47µ 16V tant

DIODES

D1,D2,D3,D4, D5,D6	All 1N4148 or equivalents

SEMICONDUCTORS

IC1,IC8	4049
IC2,IC5	4017
IC3	4040
IC4,IC11	555
IC6	2532
IC7	4081
IC9	4028
IC10	4013
IC12,IC13,IC14, IC15,IC16	4099 (5 off)
IC17,IC18,IC19, IC20,IC21	2003 (5 off)
IC22	78M05

MISCELLANEOUS

TX1, 0–6/0–6 @ 6VA p.c.b. mounting transformer (RS 207 829); REC 1, bridge WO–01 (1A); neon indicator with internal resistor, panel mounting; fuse clips (2 off); panel mounting fuse holder, 20mm; IEC mains inlet socket and plug; aluminium for heatsink, with heatsink compound; 50-way D-type plug and socket set (or outlet socket of choice); tinned copper wire, turret tags, connecting wire, mounting hardware; p.c.b.; case/box to suit (see text).

EXTENSION PROM BOARD

CAPACITOR

C1	22u 16V tant

SEMICONDUCTORS

ROM2,ROM3, ROM,ROM5 ROM6	2532 (5 off)

MISCELLANEOUS

24-way and 16-way header/ribbon cable assemblies (see text); 24-way sockets (6 off); 16-way socket (1 off); tinned copper wire; insulating sleeving; p.c.b.; mounting hardware.

For details of the p.c.b. design see page 32 and the p.c.b. service.

clock is taken to a test point, TP3, and can be enabled as follows: connect a small jumper lead to zero volts (YP1) and short the cathode of diode D6 to the other end. This will prevent the '7' reset pulse from triggering the flip-flop, IC10, or from resetting the time out 55, IC11. Thus IC4 is not reset on pin 4, and the clock free-runs at about 40kHz. This can be checked with a counter or scope on TP3, and should be a nice 'clean' square wave, of almost equal mark to space.

While carrying out this test, any program PROM will be addressed at the full clock rate, so the display will be a blur.

If the suppression lines are used, care must be taken to ensure that they are connected to the correct side of the load. Failure to do so can destroy the output drivers. Treat the suppression lines exactly the same as the cathode of the suppression diode usually connected across the coil of a relay.

Connecting the low side of the 5V power supply to mains earth was found to reduce some problems encountered with mains borne interference. If this could prove to be a problem in your particular environment, and earthing does not completely clear the problem, using an in line connector, like the one used in the PROGRAMMER unit, will almost certainly do so. PE

REDBOXES REVIEW

BY RAY STUART

Red leader to control!

At long last, computers in the home can actually do something useful. Practical Electronics has for years been showing how to build useful computer add-ons such as mains controllers, alarm systems, and detectors. Now, as we predicted, a commercial "add-on system" is now available – Red Boxes. We can put it to the test and the results were quite impressive.

One area in which home computers could usefully be employed is that of home automation. Imagine having the curtains automatically close when it gets dark, and room lights turning on when you enter a room. It is true this has been possible for some time, but as this usually requires extensive, and costly, modifications to the house wiring not many people have attempted to do it. However, all this has changed thanks to a new product called Redboxes.

WHAT IS THE REDBOXES SYSTEM?

The Redbox system consists of a number of units communicating with each other, and a home computer, via the existing house wiring by using a technique called mains-borne data transmission. This technique can be likened to radio transmissions except the transmission medium is the house wiring instead of the air. In fact the devices modulate a 129 KHz carrier with data which is then injected onto the mains. At the receiver this signal is separated from the 50 Hz mains and demodulated to reveal the data. The Red Boxes system currently consists of three different units, Red Leader, Red One and Red Two and is available for a range of home computers.

Red leader, as the name suggests, is the system controller. It is a complete 6502 based microcomputer that runs its own version of BASIC, about which more will be said later. Red Leader is programmed by a home computer via an RS232 link. It should be noted, however, that the home computer acts only as a terminal and can therefore be removed once Red Leader is programmed where upon it transmits and receives, via the mains, encoded data to and from Red One and Red Two. Regular readers will not be surprised to know that I tested the BBC Microcomputer version.

Red One is an electronically controlled 13 amp switch. It is simply plugged into any convenient mains socket and the appliance to be controlled is plugged into Red One. Upon receipt of an appropriate command from Red Leader the appliance can be switched on and off. In addition a small switch is fitted to allow manual switching if required.

Red Two is an infra-red sensor that can detect movement over a wide angle and up to a distance of several metres,

Photo.1. *Red Boxes basic set-up*

it will also detect a fire. When either of these is detected Red One sends a message to Red Leader which can then take appropriate action.

DATA SECURITY

The manufacturers claim that, even though it would normally only be used within one house, the system can transmit data over a distance of about 400 metres; I successfully tried Red One in a friend's house some 250 metres away. Now you may think that with this kind of range it is possible for two systems to interfere with each other causing all sorts of havoc, but you would be wrong. Each Red One and Red Two has a unique address, and in addition, each packet of data has a secret key which is further encrypted with a random number. This random number is changed with each transmission to further enhance security. With almost one million device addresses available and over 16 million keys the possibility of more than one device being accessed is prevented.

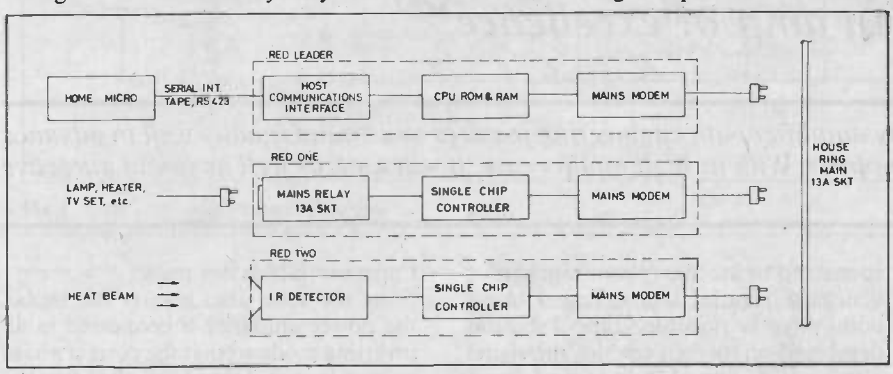


Fig.1. *Block diagram of the basic Red Box and starter kit*

INSTALLING THE SYSTEM

Installing the system is straightforward as the units are simply plugged into existing mains sockets as required. One thing that infuriates me when I buy electrical devices is to find, usually just after the shops have shut, that I have not got a spare mains plug. The manufacturers are obviously aware of this and not only supply the units with fitted mains plugs but also supply wall mounting brackets, screws and wall plugs. Once installed the system can be operated in one of two modes. The first mode allows the units to be controlled by the home computer's keyboard, in the other the home computer can be removed whereupon Red Leader takes complete control.

USING THE SYSTEM

The home computer is put into terminal mode, (on the BBC simply type *FX2,1), after which Red Leader is switched on. The computer displays a control panel via which the system can be programmed. This is mode one. In order to make the system user-friendly this part of the programming is menu driven. That is to say all commands are listed on the screen and evoked by entering a single character. The system responds by prompting the user for the required information, thus it can be operated without having to have any knowledge of programming techniques. However, compared with the other mode, the range of operations is limited.

First Red Leader has to know the identity of any Red One and Red Two units being used. Each unit has a unique 18 digit identity number which should be entered together with an arbitrary device name, LAMP for example. This is repeated for all the devices used and a list of them is displayed on the screen together with their current status i.e. on or off. Red Leader has a real time clock which can also be set via the control panel. Individual devices can be switched on as required, be programmed to switch on at a particular time and off at another or be controlled by the status of another device. For example, Red One could be switched on when Red Two detects movement. It took me three attempts before I entered the identity numbers correctly, so I was thankful that the designers have provided a SAVE command allowing the data to be saved on the computer tape or discs, and a LOAD command to transfer it back. The menu has a QUIT command which allows Red Leader to be programmed in Red BASIC.

RED BASIC

Red BASIC is an extended version of BASIC with a strong resemblance to BBC BASIC. This is not surprising when you learn that the head of Red Boxes is none other than Chris Currey, co-founder of Acorn Computers. The additional statements and commands, such as TELL and STATUS, allow units to be monitored and controlled. If you have used any version of BASIC before you should have no problems using Red BASIC. When Red BASIC is invoked it responds by displaying the] character as a prompt, the unit can now be programmed using the home computer as a terminal. This is an important feature as the home computer is not required once the Red BASIC programme is run.

A sample programme is shown below:–

```
10 IF DEVICES = 0 THEN END
20 PRINT 'Name', 'Status'
30 FOR device= TO DEVICES
40 PRINT NAME$device,
   STATUS$devices
50 NEXT device
```

When RUN the home computer will display something like:

```
Name      Status
LAMP      ON
SENSOR    OFF
```

When the complete programme has been entered it can be SAVEd and LOADed to or from tape or disc.

With this sort of computing power complex systems can be implemented. Should it be necessary, the home computer can remain connected to allow user defined messages and graphics to be displayed under control of Red Leader.

APPLICATIONS

Applications for Red Boxes include security systems and home automation, and more as new units become available. Further units currently under development include analogue input/output devices, light dimmer controls, RS232 interface units, and door and window contacts switches. The RS232 interface units will allow computers and periphal devices such as printers to be inter–connected. With a range of 400 metres it could allow you to communicate with a friend's computer. One addition I would like to see is a battery backed RAM facility for Red Leader so that a programme is not lost due to a intermittent mains failure, particularly important in a security system.

STARTER PACK

A Red Boxes starter pack is available for use with the BBC Micro, Commodore 64 Spectrum 48K and 64K and Amstrad computers. The pack contains three units, Red Leader, Red One and Red Two. Each unit is housed in a custom moulded red plastic case and supplied with a red mains lead and red mains plug, hence the name Red Boxes. The kit also contains the necessary mounting brackets, screws and wall plugs, and an RS232 cable to suit the selected home computer. BBC users should note that even though the computer end of the RS232 lead is marked TOP, it is fitted with this mark facing the analogue port. I particularly liked the easily understood 50 page user guide, a refreshing change from those supplied with some systems.

The starter pack costs £130 inc VAT, additional Red Ones and Red Twos are available at £36.95 each. Full details are available from: General Information Systems, Croxton Park, Croxton, Cambridge, PE19 4SY. PE

THE PE 30 PLUS 30

PART ONE BY GRAHAM NALTY

An amp of excellence!

The PE 30 + 30 is a very high quality amplifier with engineering features and sound quality well in advance of any comparable manufactured amplifier. With its high quality case, it will look as well as sound attractive in any hi-fi environment.

IT WAS originally intended to aim the PE 30 + 30 at a £100 budget, but this proved too ambitious and I see no advantage in sacrificing sound quality for a lower price when more readers will probably want to build their amplifier better than the original – and this article will give quite a few suggestions in this direction. At the final count the cost of building the PE 30 + 30 works out at just over £140.

An audio amplifier needs a good clean power supply free of ripple voltage generated either by rectification or by currents drawn by other amplification stages. The power supplies are separate right back to the mains transformer. This results in much greater clarity and stereo imagery than if one DC supply was used. The circuits for low and high current stages of the power amplifiers are separated so that the high currents drawn when speakers are being driven at high levels do not affect the sensitive input circuitry. A single power supply is used for both output stages. Separate circuits would result in better sound, but would also add considerably to the cost and size of the amplifier. However, the separation of low current supplies to different parts of the circuit is very cost effective as the parts required are not so costly.

The disc preamps are built around very simple circuitry using no negative feedback. The first stage transistor is biased via a resistor from a 1.2v supply obtained using two conducting silicon diodes in series. This gives a high input impedance which enables lower value high quality plastic film capacitors to be used without compromise on space or cost. A tantalum coupling capacitor is used for the MC input. Although plastic film capacitors would give better sound, they would be more prone to hum induced from the mains transformer. Radio frequency interference rejection is achieved with C2 in the MC stage and with R12 and C5 in the MM stage.

The input switching permits the use of disc plus two line inputs together with record and play facilities for two tape recorders. Although the tape sockets are DIN type their signals should be connected to the line (phone) sockets of your tape recorder. Tape to tape dubbing both ways is possible. Tape 1 button depressed on its own enables the signal playing to be recorded on to tape 2 and to feed the power stages of the amplifier. Tape 2 button depressed enables tape 2 signal to be recorded on to tape 1 and to drive the amplifier output. Depressing both tape buttons enables the signal on tape 1 to be recorded on to tape 2 whilst the monitor output of tape 2 can be heard via the amplifier. This facility may be quite useful when you want to hear the output during dubbing.

The tone amplifier input buffer is an emitter follower (TR6). This feeds a variable frequency network formed from R27–R30, C14–C17 and VR3 and VR4. As the sliders of the pots are moved, the impedance of one leg of the feedback chain increases whilst the impedance of the other leg decreases. The gain at any frequency is determined by the ratio of the impedances of the two parts of the network. The gain at bass frequencies is controlled by VR3 and at treble frequencies by VR4. Capacitor C18 is not used.

As the tone amp inverts the signal, the power amplifier is connected in an inverting mode so that the correct phase response is achieved at the speaker output. The power amplifier design is fairly standard, but has a number of very important features which are all very relevant to sound quality.

1. Cascode transistors TR11 and TR12 not only improve open loop high frequency gain, but also improve power supply ripple rejection as ripple present in the supply lines are filtered by R41/D11 and D12. This prevents ripple from reaching the collectors of TR9 and TR10.

2. The use of two transistor constant current sources TR13/TR14 and TR18/TR17 achieves a much higher dynamic impedance than the single transistor/two diodes constant current source. The dynamic impedance (and ultimately the sound quality) can be further improved by replacing R39 and R43 with constant current diodes J505 and J507.

3. Cascode transistor TR16 holds the collector of TR15 at constant voltage, considerably improving its linearity.

4. The use of T0-220 type transistors

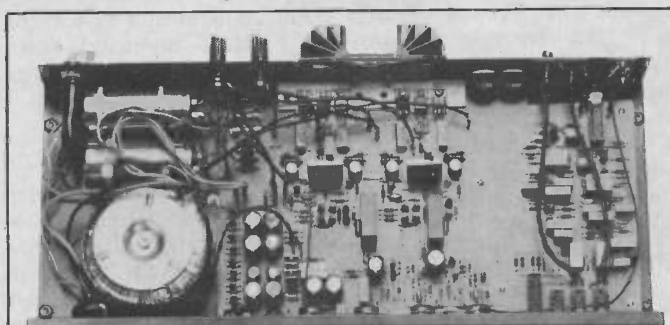


Photo.1.
Internal view of the PE30+30

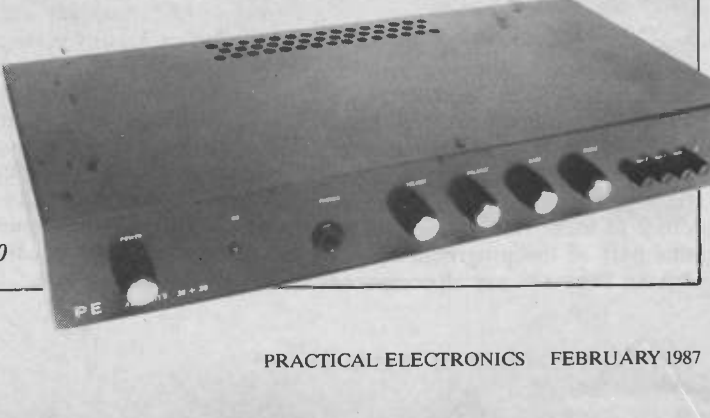


Photo.2.
External view of the PE30+30

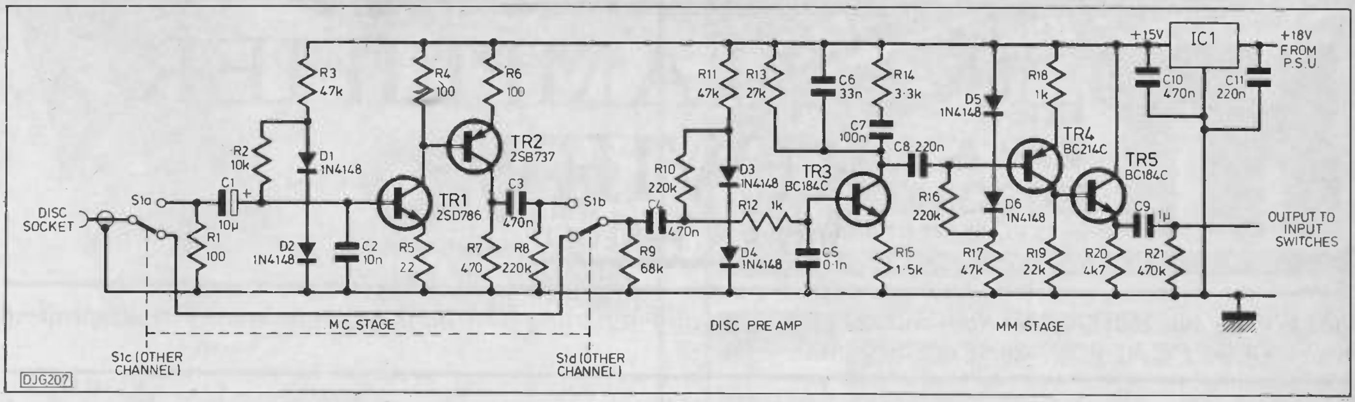


Fig.1. *Disc pre-amp circuit diagram*

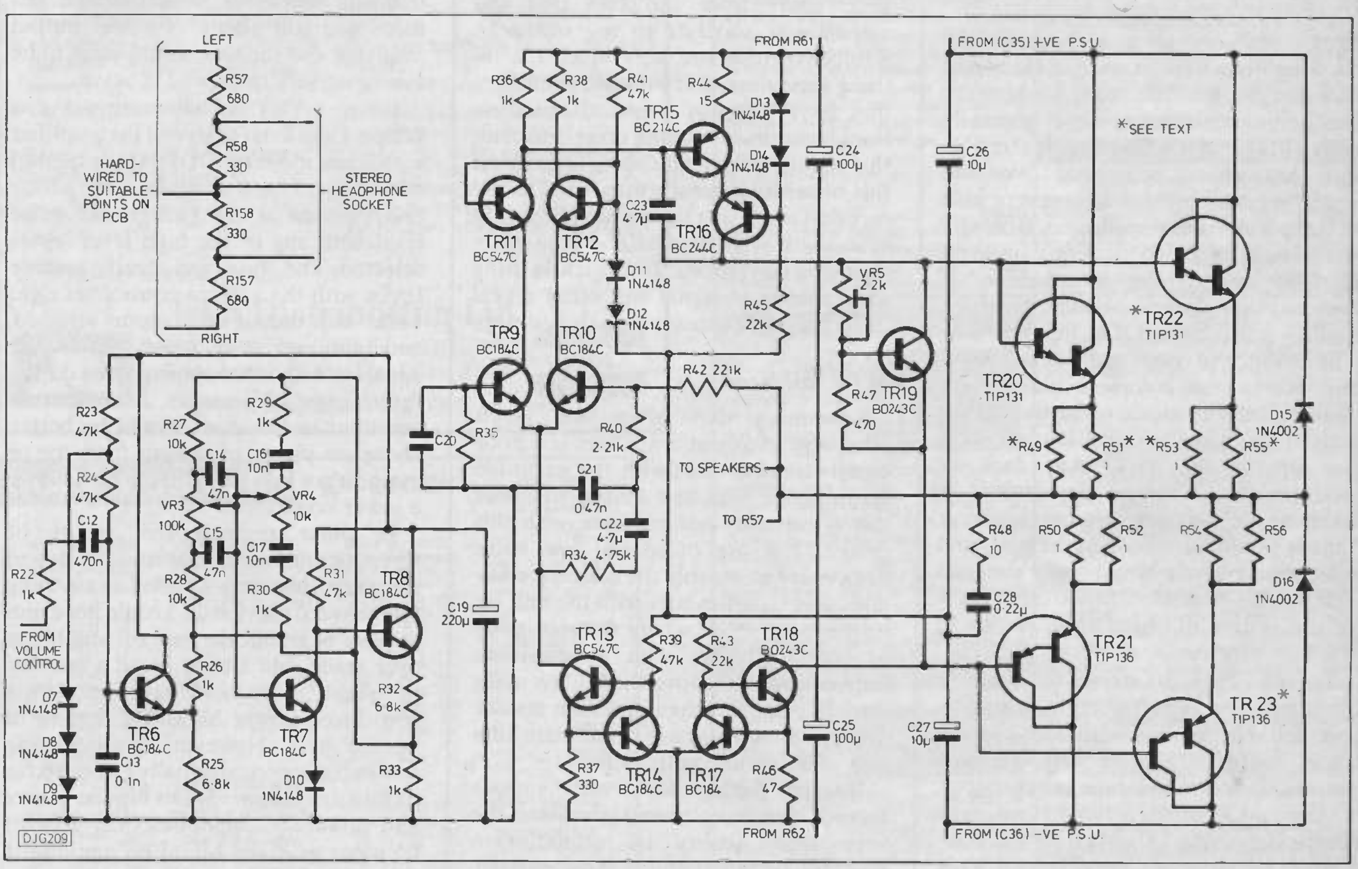


Fig.2. *Tone and power amp circuit diagram*

for TR16 and TR18 and fitting them close together on a joint heat sink achieves fast dissipation of the changes in heat caused by the varying level of the audio signal. As a result, the junction temperature is kept very steady and changes in gain (giving rise to Temperature generated distortion) due to temperature variations is very greatly and audibly reduced.

5. The bias transistor is a T0-220 type of low thermal resistance. As a result the bias transistor follows the changes in temperature of the output devices very closely and the amplifier sounds better as a result.

6. The output transistors are darlington types. The advantage is that the drivers, being inside the package have a low thermal resistance to the heat sink without taking extra space.

7. As a result of the close thermal tracking of the bias transistor, a lower value emitter resistor can be used, giving better linearity of the output stage. The actual component quality affects the sound and space is provided on the board to fit a pair of Holco 1W 1RO resistors in parallel.

8. Holco resistors of high sonic quality are used in the critical feedback positions R34, R40, R42.

9. Space is provided for a second pair of output transistors for readers who require high output current capability. Higher power can be obtained by using a transformer with a 25-0-25v secondary.

All components except the mains transformer, switch and reservoir capacitors are mounted on a single p.c.b. This reduces the internal wiring to a minimum. Cables of fairly high current rating should be used for wires to and from reservoir capacitors and speaker terminals (3–6A).

It is wise to follow a planned procedure when building a project such as this. Whenever I build a PCB, I follow the same order – wire links, terminal pins, diodes, resistors, semiconductors and then capacitors. This way I avoid the problem of trying to fit a small component in the space between two or more large capacitors. With the availability of both four bar and five bar resistor colour codes it is wise to have a meter on hand to check resistor values before inserting them into the board.

PART TWO: NEXT MONTH

PE 30 + 30 AMPLIFIER REVIEW

BY R.A. PENFOLD

Just to make sure that Graham Nalty was not blowing his own hi-fi trumpet too hard, we commissioned an independent review of the PE 30 + 30 – these are the results.

"The results were as good as anything that I've heard previously".

TEN years or so ago, high quality amplifiers were in great demand and new designs, whether ready made or for the home constructor, were generally met with great enthusiasm. Interest in hi-fi has waned somewhat over the years, presumably due to a severe case of 'seen it all before' syndrome. Recently there has been a revivification of interest in hi-fi due to the introduction of compact disc players, and the very high quality source signal that they provide. The absence of 'hiss' and 'clicks' allows the music, the complete music, and nothing but the music to be heard, but only if the amplifier and loudspeakers are up to the task. Any lack of performance in either department is likely to be very much more apparent than it would have been in the past, and a lot of people who have bought compact disc players have modernised other parts of the system in order to do justice to the new medium.

The PE 30 + 30 stereo amplifier is intended to be an extremely high quality unit suitable for use with any normal signal source, including compact disc players. It sports two tape input/output sockets, a CD input, a tuner input, and a cartridge input. A switch at the rear enables the latter to be set to suit both moving coil and moving cartridge types. The low profile styling is made possible by the use of a toroidal transformer and horizontal mounting of the hefty smoothing capacitors. Very high quality capacitors, resistors, and semiconductors are much in evidence when the top cover of the case is removed, with an obvious lack of electrolytics in the signal path. The design originates from 'Audio Kits' incidentally, who specialise in very high quality components for hi-fi use including resistors which each cost the sort of money that you would normally expect to buy a hundred or even a thousand of these normally cheap components.

ACID TEST

Simply using the right ingredients does not automatically provide palatable results, so how does the PE 30 + 30 amplifier actually perform? A few quick checks with the test equipment proved little apart from the fact that the amplifier is superior to my test gear. Subjective tests are very much the in-thing these days, and with two amplifiers that have virtually identical specifications sometimes souding quite different, this is quite understandable. The reason this occurs is generally attributed to the fact that real input signals are not steady sinewaves, but complex and constantly changing waveforms. Tests such as using short bursts of signal will often reveal differences that steady signals will not.

LOW HISS

Something that often lets down otherwise excellent amplifiers is a poor signal to noise ratio with the cartridge preamplifier switched into circuit, but this is certainly not the case with this design. The use of special low noise devices is presumably the reason for low 'hiss' level, particularly with the unit set to the 'MC' mode where the sensitivity is very high (but with a low input impedance) and conventional low noise devices offer less than optimum results. There is a total absence of the main hum that afflicts some amplifiers.

Results during tests with various records were very encouraging, and the very high quality of reproduction provided by this amplifier is undeniable. Many amplifiers can provide good results when dealing with medium power levels and predominantly mid-band frequency components. It is at the extremes of the power and frequency ranges plus rapid changes in dynamic levels that sorts out the true super-fi designs from the interlopers. Tests were made with various types of difficult material including cymbal crashes, organ music, and Stravinski's 'Rite Of Spring'. I am not a paid-up member of the hi-fi writers union and so I will refrain from waxing lyrical about this amplifier, but it always gave a clean sounding output with no signs of distress on any of the test passages. Passages having powerful high frequency signals are less than convincing with many amplifiers, including some up-market types, but this design handles this type of thing particularly well. The amplifier used for test purposes was actually fitted with a lower voltage mains transformer than will be used in the final design, but there was still plenty of power output available and the unit would seem to be conservatively rated at 2 × watts.

Being a very definite compact disc fanatic I was keen to try out the amplifier with some modern 'DDD' (fully digital) recordings. I must admit to being a little disappointed at the background noise level with any of the high level inputs selected. The 'hiss' was clearly audible (even with the volume control set right back) with one of these inputs selected, and although the noise was never apparent with a disc playing, even during the quietest of passages, I feel that an amplifier in this class should be better. There are plenty of designs from ten or more years ago which seem to achieve a lower noise level.

In other respects the quality of reproduction was all that could be hoped for, the results were as good as anything I have heard previously. I could not claim to have heard all the super-fi amplifiers ever made, but I have heard a number of quality units and have previously considered power MOSFET designs to be the best. However, despite being somewhat sceptical initially I would have to rate this design with its bipolar power and power Darlington devices at least on a par with any MOSFET amplifier I have ever heard.

CONCLUSION

The unit is mechanically strong and neat, has all the inputs you are ever likely to need, but apart from a headphone socket and click-stopped centre settings on the tone controls it is free of any frills. However, it was designed for the hi-fi enthusiast who is interested first and foremost in sound quality, and anything remotely gimmicky is not normally included in designs of this type (some do not even have tone controls). The real test of hi-fi equipment is whether or not you can listen to the music remaining oblivious to its presence. The PE 30 + 30 amplifier passes this test apart from the noise level on the CD input mentioned earlier. This is only a minor quibble though, and it would certainly not stop me from building one. PE

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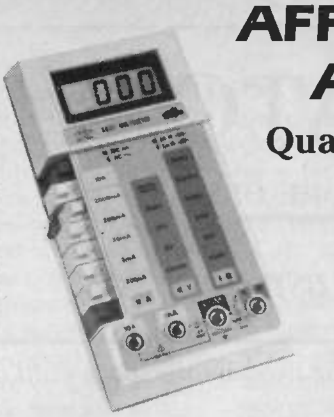

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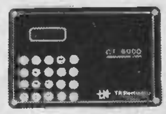

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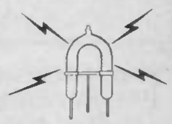

Designed to produce a high intensity light pulse at a variable frequency of 1 to 15Hz, this kit also includes circuitry to trigger the light from an external voltage source (eg. a loudspeaker) via an opto isolator.

Instructions are also supplied on modifying the unit for manual triggering, as a slave flash in photographic applications or as a warning beacon in security applications. The kit includes a high quality pcb, components, connectors, 5Ws strobe tube and full assembly instructions. Supply: 240V ac. Size: 75x50x45.

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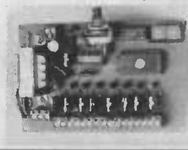

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SPACEWATCH

BY DR PATRICK MOORE OBE

Our regular look at astronomy

Venus: the Schroter effect plus news from the two famous space-craft of 1986.

THE two most famous space-craft of 1986, Voyager 2 and Giotto, are continuing their journeys. Voyager 2, having left Uranus far behind, is now in what is termed 'cruise mode' with most of its experiments switched off, but it is hoped that it will be in full operation for the pass of Neptune in 1989. Giotto, which had a rough ride through the heart of Halley's Comet in March 1986, has lost its camera, but many of the other experiments are working, and it may well be that further work can be carried out. Giotto will be back in the neighbourhood of the Earth in 1990, and it is possible that it may be sent on to rendevous with another comet.

Considerable attention is being paid to the Sun at the present time. The last maximum was curiously 'double', and since then activity has been generally rather low, though there have been occasional outbursts – as at the time of the perihelion of Halley's Comet, when a solar flare blanked out all messages from Pioneer Venus, which alone was in a position to monitor the comet! During 1986 there have been many spotless days. American astronomers now forecast that solar minimum will occur in July 1987, and the next maximum at some time during the summer of 1991, though it is never possible to tell just how the Sun is going to behave. In any case, we cannot expect major spot-groups or displays or auroræ for some time yet. Looking still further ahead, a Chinese forecast gives a minimum in the spring of 1998 and a maximum in the autumn of 2002.

For some time we have been hearing about 'gravitational lenses', which involve a massive object splitting up the light from a more remote source (usually a quasar) and making the remote source appear double. Seven instances have so far been tracked down with fair certainty. Now an American team has found that QSO 2345 + 007, a double-imaged quasar in Pisces, has an apparent separation of over seven seconds of arc. No visible lensing galaxy has been found, and the researchers conclude that the body responsible must be 'compact', with a mass at least thirty times that of a large galaxy such as the Andromeda Spiral. Just what this compact body may be is still a matter for conjecture.

VENUS: THE SCHRÖTER EFFECT

During this January, Venus is a magnificent object in the morning sky – even for British observers, though its declination is well south of the celestial equator. The planet reaches its greatest western elongation (47 degrees) on the 15th, and the maximum magnitude is −4.5, much brighter than any other star or planet.

At western elongations, of course, the phase steadily increases. Theoretically,

The Sky This Month

THIS time last year we were still looking forward to the best part of the return of Halley's Comet. Now, alas, the comet has disappeared from the view of all except the owners of large telescopes. If you feel inclined to look for it, the position on 1 January is RA 11h 29m.4, declination 160S 16', close to the star Delta Crateris; but it has lost its coma and tail, and now appears as nothing more than a dim, blurred starlike object.

Of the planets, Mercury is out of view. Venus is a brilliant morning object, and will be only 1.8 degrees north of Saturn on the 24th, in the constellation of Ophiuchus. Mars and Jupiter are close together in the Pisces/Aquarius region, and are easily observable after sunset. Jupiter, at magnitude −2.2, now far outshines Mars, whose magnitude has dropped to 0.8 – about the same as that of Aldebaran, though at opposition. Last summer, Mars actually outshone Jupiter or any other object in the sky apart from the Sun and the Moon.

The Moon is full on the 15th and new on the 29th. There are only two eclipses during 1987, both of the Sun – and neither is visible from the British Isles.

The main meteor shower this month is that of the Quadrantids, which usually has a short, sharp maximum, due this year on 4 January at 3h – early morning. This should be a favourable maximum, and at their best the Quadrantids can be really spectacular, with a z.h.r. of at least 80. (The z.h.r., or zenithal hourly rate, is the number of shower meteors which might be expected to be seen with the naked eye by an observer under ideal conditions, with the radiant at the zenith; in practice, of course, these conditions are never fulfilled, so that the observed rate is always less than the z.h.r.) There is no known comet associated with the Quadrantids, which derive their name from the old constellation of Quadrans Muralis (the Mural Quadrant) deleted from modern maps. The nearest bright naked-eye star to the radiant is Beta Boötis, not far from the brilliant orange Arcturus.

The brilliant winter star-groups now dominate the night sky. Orion is at its best, fairly high in the south after dark; the starry Belt points upward to the orange Aldebaran in Taurus (the Bull) and downward to Sirius in Canis Maor (the Great Dog), which shines as the brightest star in the sky even though it is very feeble compared with celestial searchlights such as Rigel in Orion. Capella, in Auriga (the Charioteer) is almost at the zenith. Close beside it you can see a triangle of fainter stars, often nicknamed the Haedi or Kids; two of these (Epsilon and Zeta Aurigæ) are remarkable eclipsing binaries, and Epsilon is particularly strange inasmuch as the eclipsing companion, which dims its primary for a while every 27 years, has never been directly detected. It was once believed to be a black hole, but is now thought to be a smaller star surrounded by an opaque cloud of material. Ursa Major, the Great Bear, is in the north-east, with Cassiopeia high in the north-west; in the east Leo, the Lion, has started to come into view in the late evening.

the illuminated part of the disk is 44 per cent at the start of the month, exactly 50 per cent on the 15th (dichotomy or half-phase), and 58 per cent at the end of the month. Meanwhile, the apparent diameter decreases from over 28 seconds of arc to only 22 seconds of arc, as the planet moves away. The phase will continue to increase during the summer until superior conjunction is reached on 23 August, by which time Venus will be more or less behind the Sun and will have been lost to view – though it will soon reappear in the evening sky.

Telescopically Venus is somewhat disappointing, because no definite surface features are visible; the planet is permanently veiled behind a layer of cloud, and it was not until the space-probe era that we had any real idea of what the conditions there really are. (They are not welcoming. The temperature is intolerably high, the atmosphere is made up chiefly of carbon dioxide, the ground pressure is about 90 times as great as that of the Earth's air at sea level, and the clouds contain large amounts of sulphuric acid, while it seems likely that there is much active vulcanism on the surface.) But there is one minor point which is of interest to observers. When the planet is an evening object, and waning, dichotomy is always early; during morning apparitions, when the phase is increasing, dichotomy is late. This was first pointed out almost two centuries ago by the great German observer Johann Hieronymus Schröter. I once nicknamed it 'the Schröter effect', and this seems to have become part of astronomical terminology! It can amount to several days.

I have given a full account of this elsewhere*, but it is always worth a check, if only because we are still not sure of its cause – though it must be linked with the planet's deep, dense atmosphere. Observers usually have difficulty in deciding the exact date of dichotomy, partly because the terminator (the boundary between the sunlit and the dark hemispheres) is sometimes irregular, and partly because it nearly always happens that several cloudy evenings or mornings intervene at the critical time! But it seems safe to assume that the next dichotomy will occur around the 26th to 29th of January rather than the theoretical 25th.

Whether Mercury, which virtually lacks atmosphere, shows a similar Schröter effect seems to be a matter for debate, but the innermost planet will be well placed during February, so that energetic observers may care to check its behaviour as compared with that of Venus – though Mercury is, of course, a much more difficult object to study.

**The Planet Venus*; Garry Hunt and Patrick Moore (Faber and Faber, London, 1984).

PE BAZAAR

LIQUID CRYSTAL DISPLAYS

BY R.A. PENFOLD

The display technology of the future

Liquid crystal displays offer many advantages such as light weight, low power and decreasing cost and are now finding their way into many applications which were traditionally catered for by CRTs. In the last few years LCD technology has come a long way!

I suppose there is a slight paradox in that l.c.d.s (liquid crystal displays) have been in common use for many years now, but they are still the subject of a great deal of research and development. One reason for the continuing development is probably the mediocre performance of most early devices. This was not just a problem of poor display quality with low contrast and restricted viewing angle, but also one of reliability. Even today l.c.d.s are fussy about their driver circuits and have an operating life which is significantly less than that of most other electronic components, but some of the early devices deteriorated to the point of being useless in under two years, and in some cases in just a few months. This led to several manufacturers pulling out of l.c.d. production or even going out of business altogether. The effects of this are still evident today, with noticeably fewer companies producing l.c.d. than (say) l.e.d.s, or most other types of components come to that.

The other reason for the continuing development of l.c.d.s is that they lend themselves well to applications which require complex displays, such as television receivers and computer displays. In other words, the type of application that would normally have a conventional cathode ray tube (c.r.t.) to provide the display. Although c.r.t.s have themselves been the subject of a great deal of research and development, they do not rival l.c.d.s in terms of compactness and power consumption, and it is difficult to envisage them ever doing so. L.c.d. technology has probably progressed more than most people realise, and there are now 'off the shelf' devices available which go well beyond the familiar 3½ digit displays, watch displays, and so on. High resolution displays for computer use, pseudo analogue displays, and even multicolour displays for television applications are now produced, and we are likely to be seeing a great deal more of l.c.d.s in the future.

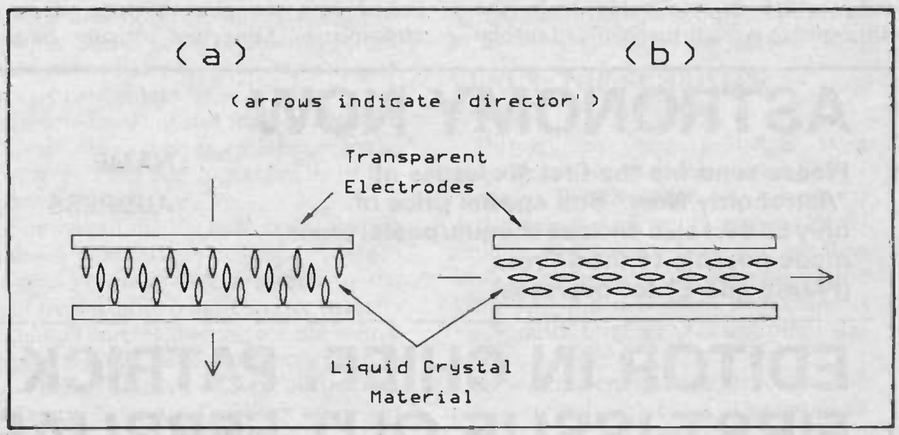

Fig.1. *(a) With now power applied to the electrodes the liquid crystal is in the 'relaxed' state and light is able to pass through the cell. In (b) the cell has been activated, shifting the orientation of the molecules and blocking the passage of most light.*

LCD FUNDAMENTALS

Liquid crystal display technology is a complex and confusing subject, and there are actually several different effects which can be used, giving rise to more than one type of display. The general scheme of things is to have two transparent electrodes with a thin layer of liquid crystal material in between them, as in Fig. 1(a). Liquid crystal materials produce a strong electro-optical effect, and consequently this layer can (and normally is) very thin indeed, at typically 3 to 50μm. The molecules are rod shaped, and with no signal applied to the electrodes (the 'relaxed' state) they are arranged in the manner shown in Fig. 1(a) so that light can pass through the device. The axis in which the molecules are aligned is called the director, and this is indicated by the arrow in Fig. 1(a). By applying a suitable potential across the two electrodes the orientation of the molecules changes to that depicted in Fig. 1(b), and the passage of light through the device is blocked.

In this basic form the display must rely on a backlight to provide a light source that causes the transparent segments of the display to apparently light up when they are in the transparent state. When using a filament bulb or other electrical light source this method can be a bit pointless, since the main advantage of liquid crystal displays is their very low power consumption, which would obviously be sacrificed by adopting an electrically backlit method. A more common arrangement is one which has the electrode acting as a reflector so that in the relaxed state ambient light is reflected from this electrode and out of the device, but when energised the path of the light is blocked. The area around the segments of the display is made reflective to match appearance of relaxed state segments, and the display therefore provides the familiar black energised segments on a silver-grey coloured background.

An obvious advantage of a passive display such as a liquid crystal type over emissive types such as light emitting diode displays is that under bright conditions they are not rendered unreadable. On the other hand, they are

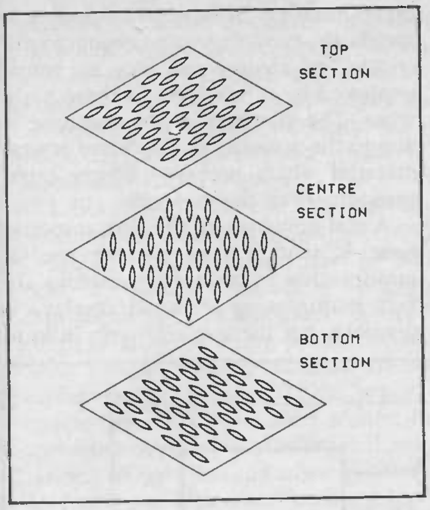

Fig.2. *Sections through twisted nematic liquid crystal in the relaxed state (the molecules when activated).*

less than ideal for applications where they will be used in low lighting levels. There are ways of rendering these displays readable in darkness without sacrificing the low power consumption, and one of these is to have a form of backlighting which relies on a chemical light source that will last around five to twenty years (the modern equivalent of the old luminous hands and numerals on watches and clocks). Another is to have a miniature bulb to provide backlighting when a switch is activated. Although displays of this type are often referred to as 'backlit' types, the ones I have encountered have in fact been illuminated from the front. Both solutions are less than perfect, and in applications where a display is likely to be read in low light levels and power consumption is not a major consideration (such as clock radios), light emitting diode and other forms of emissive display are still the more common choice.

A liquid crystal of the type described above is the basic 'nematic' type, and although many of the early displays were of this type, modern displays are generally of the 'cholesteric' or 'twisted nematic' type. The problem with the basic nematic displays is that they are only readable over a rather narrow range of viewing angles, and well off axis the active segments completely disappear.

With a twisted nematic display the two electrodes are coated with a material that lines up the molecules in a certain way, but the electrodes are positioned at 90 degrees to one another. This gives a structure of the type shown in Fig. 2 which represents three slices taken through the liquid crystal material (at each electrode and half way between the two). The point to note here is that the director twists through 90 degrees from one electrode to the other. With cholesteric liquid crystals there is the same twisting of the director, but by greater amounts.

If the pitch of the 'twist' is suitable, light travelling through the liquid crystal will be twisted or changed in phase. By applying a potential across the electrodes the molecules are made to shift more or less perpendicular to their relaxed state positions, and light passing through the device is then no longer subjected to the phase change. In itself this does not provide the ability to enable or block the passage of light through the device, but with the aid of polarising filters light of one phase can be blocked while light of the other phase is not. The usual arrangement is for light to be steered through the cell when it is in the relaxed state, and blocked when it is activated. The way in which this system operates is illustrated in Fig. 3. This system is not just suitable for backlit displays, and it will work properly in conjunction with a reflector. It provides displays of good contrast over a wide range of viewing angles.

GUEST-HOSTS

The guest-host effect is obtained by adding special dyes known as 'pleochroic' dyes to the liquid crystal, and these have rod shaped molecules which tend to align themselves in sympathy with the liquid crystal molecules. Thus the dye molecules are the 'guests' of the liquid crystal 'host' molecules, and it is from this that the name of the effect is derived.

A pleochroic dye absorbs light more or less strongly depending on whether the light is polarised parallel or perpendicular to the axis of the rod-like molecules. By changing the orientation of the director the axis of the dye molecules is also shifted, and in conjunction with a polarising filter a change in colour can be obtained. In other words a sort of voltage controlled optical filter is produced, and it would presumably be quite accurate to describe a device of this type as a v.c.f. Provided the dye and liquid crystal molecules are accurately matched, and the absorption of the dye is relatively high so that only a small quantity is required, this system can be very effective with a reasonably short response time.

RELIABILITY

Reliability problems were mentioned at the beginning of this article, and these all revolve around maintaining the liquid crystal free from any contamination. The easiest way of producing contamination is to drive the device with a d.c. signal. It is a common misconception that liquid crystal displays will not respond to d.c. drive signals, but in fact they will do so. However, this gives so-called 'burning' of display segments which fail to work properly after a fairly short period of operation (as little as a few hours). What actually happens is that an electrolytic action produces contamination which soon renders the liquid crystal material useless.

Using an a.c. signal is the standard approach to avoiding electrolytic problems, but in order for this method to be effective it is essential to have no significant d.c. component on the drive signal. In the case of liquid crystal displays the d.c. component normally has to be kept to less than about 25mV to 50mV.

The liquid crystal cells must be hermetically sealed as they would otherwise react with the atmosphere, particularly with any water vapour in the atmosphere, which could lead to chemical decomposition. It is also important that the electrodes or any part of the display that comes into contact with the liquid crystal material will not eventually cause contamination that will lead to the failure of the device.

Most modern liquid crystal displays have an 'expected' operating life of at least five years, and are certainly superior to the original devices in this respect. On the other hand, an operating life of this order is much less than that

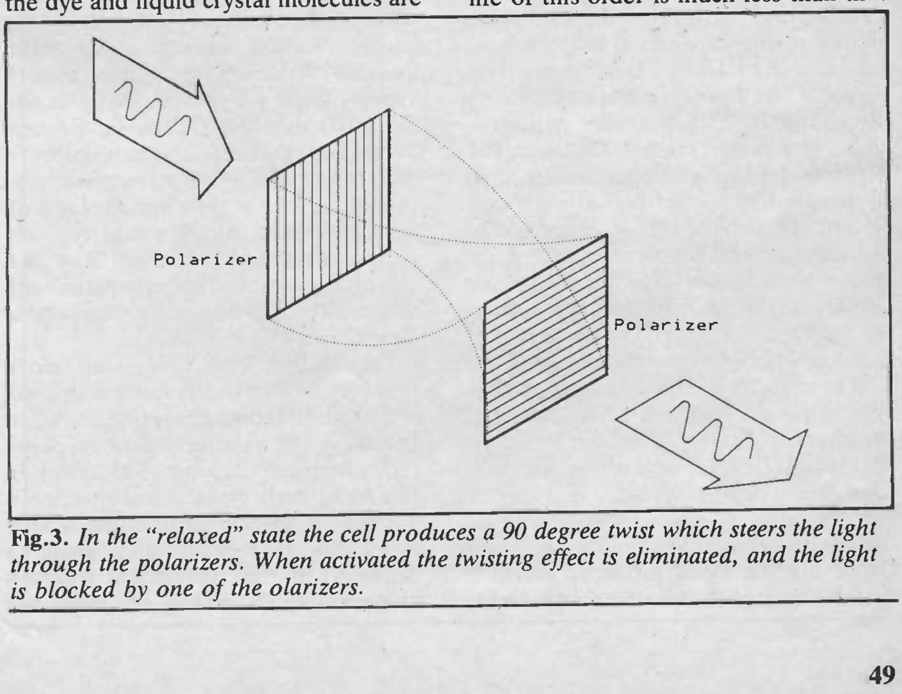

Fig.3. *In the "relaxed" state the cell produces a 90 degree twist which steers the light through the polarizers. When activated the twisting effect is eliminated, and the light is blocked by one of the olarizers.*

of most other types of electronic component, including l.e.d. displays (only about half that of filament displays!). It means that with some of the cheaper products that use liquid crystal displays, including many watches and calculators, the life of the product is likely to be determined by the staying power of the display, since the cost of replacing the display would almost certainly be greater than the value of the product. I have certainly had one or two products with liquid crystal displays which have fallen into this category.

With more expensive products such as cars and up-market cameras it would obviously be financially viable to replace a failing display, and with something like an expensive camera which might be expected to last for twenty to thirty years (and quite possibly much longer), there is the prospect of having to replace the display several times during the lifetime of the product, assuming that replacements remain available. The adoption of liquid crystal displays in many expensive products would tend to suggest that the manufacturers of these goods have faith in the medium and long term reliability of these devices, or is it simply that there is presently no viable alternative in applications that require micropower operation? This is something that will become apparent in the fullness of time.

DRIVING

Liquid crystal displays are not normally in the form of completely separate cells for each segment of the display, but usually have a common lower electrode which is termed the backplane, with individual connections to the other electrodes. Most circuits which use liquid crystal displays utilize special driver integrated circuits which provide suitable a.c. drive signals. This is not achieved by earthing the backplane and feeding the other inputs with a.c. signals, and the most common arrangement is to drive the backplane with a squarewave signal which has an accurate 1 to 1 mark-space ratio. This signal is often generated via a divide by two flip/flop circuits which ensures a suitably accurate mark-space ratio. The individual segment electrodes are then driven from an open circuit output if they are to be switched off, or connected to an accurate mid-supply reference point if they are to be activated. The backplane is switched symmetrically either side of the reference level giving the required a.c. signal across the activated cells.

There is an alternative arrangement where each segment is driven from an ordinary logic signal via a two input exclusive OR gate, with the spare inputs and the backplane driven from a squarewave signal. This general arrangement is outlined in Fig. 4. If you work out the signal produced across a cell for each of the two input logic levels you will find that with the input low the squarewave signal appears at both the individual cell input and at the backplane. In other words there is no potential difference across the cell, and it is set to the relaxed state. With the input taken high things are very different, and the exclusive OR gate effectively becomes an inverter. This gives antiphase squarewave signals across the cell, driving it with an a.c. signal with a peak to peak value of almost double the supply voltage.

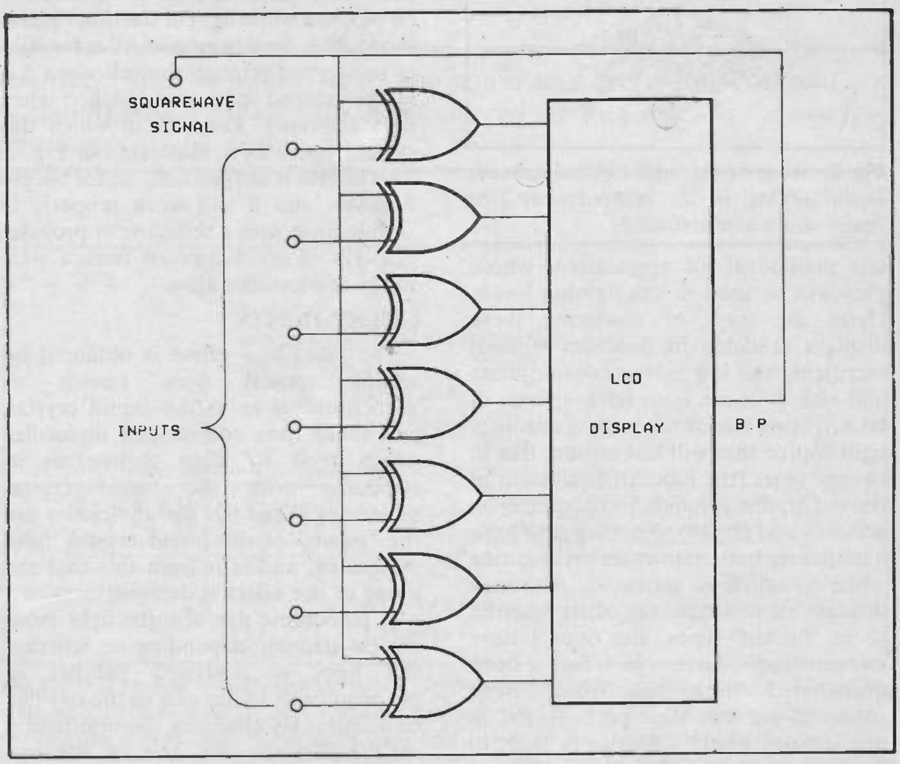

Fig.4. *Driving an l.c.d. via XOR gates*

The drive voltage requirement varies between about two and twenty volts peak to peak, and operation from low voltage battery supplies is possible with many devices. There is usually plenty of latitude as to the precise drive voltage, with higher voltages generally giving wider effective viewing angles. Most modern displays are usable over a viewing angle range of around plus and minus 60 degrees. Of course, the real attraction of liquid crystal displays is their low drive current requirement, and something like a 3½ digit display with all segments activated would typically require a total of only about 2 or 3μA of drive current. This compares with about 100 to 300mA for a comparable high efficiency l.e.d. display.

The acceptable range of drive frequencies is normally quite restricted, with 30 to 100 Hertz being typical. Allied to this is the relatively slow response time of typically around 75 to 100ms. In fact some early types seemed to find it difficult to keep up with a one second count on a clock display, giving a decidedly blurred image, and although modern liquid crystal displays are exceptionally slow by electronic standards, they appear to change quite crisply and cleanly and they are much improved in comparison to these early types. The slowness of the response is due to the viscosity of the liquid crystal material which prevents a very rapid realignment of the molecules.

A real drawback of the slow response time is that it prevents the use of multiplexing in multidigit displays. In fact multiplexing of small displays is possible, but there is relatively little to be gained by multiplexing these, and it is with medium and large displays that multiplexing has the most to offer. There is an alternative to multiplexing that has been adopted for some displays, and this technique is known as 'triplexing'. It is basically just a 'rows' and 'columns' arrangement which enables displays as large as eight digit types to be driven from a single integrated circuit (albeit a 40 pin type in most cases). The necessary drive signals are highly complex though, and it is only a practical proposition when using a special driver integrated circuit. Actually most liquid crystal displays have matching driver devices and it is unusual for them to be driven in any other way. Although single and double digit l.e.d. displays are readily available, there seems to be no liquid crystal equivalent to these. A 3½ digit type seems to be the most simple form of liquid crystal display that is widely available.

DEVICES

A useful range of standard multidigit liquid crystal displays is available, ranging from simple 3½ digit types to 8 digit triplexed displays. Many types have additional segments to provide '+' and '−' indication, 'batt. low' indication, etc. For every liquid crystal display you are almost certain to find a matching driver of some kind, and popular choice for home-constructor projects is the ICL7106 digital voltmeter chip driving a standard 3½ digit display.

Liquid crystal displays now go well beyond simple multidigit displays though, and a lot of much more complex displays are now being produced. The most widely available of these are the alphanumeric displays. These are not exactly new and have been around for a number of years, but the original types tended to have limited capacity (about 16 digits) and high cost. The latest types offer typically something like two rows of 40 digits, with each digit being made up from a 5 x 7 dot matrix. In other words, the display has around 1400 cells, which could obviously make driving the device something of a nightmare. In fact there is no problem here as these devices have built-in drivers, and from the interfacing point of view they are very much like an ordinary microprocessor peripheral device. The built-in drivers are more than that, and they often provide an extended ASCII character set, plus facilities such as a flashing cursor and left or right scrolling. With some justification these are often termed 'intelligent' displays.

Taking the RS range of alphanumeric displays as an example of what is available, these range from a simple 16 x 1 type to a 40 x 4 display. They are suitable for interfacing to both 4 and 8 bit systems (although 4 bit systems are often regarded as obsolete they are still widely used in some control applications). An integral character generator ROM provides a range of 192 characters including the full ASCII set, and there is provision for up to eight user defined characters. The devices are governed via a number of control registers which enable the desired display to be produced with a minimum of work by the microprocessor (and the programmer).

The obvious application for these displays is in portable computer equipment, but they are also suitable for such things as shop window displays and medical or other monitoring applications. Obviously ordinary monitors could be used in these applications, but these are less than ideal for situations where they will be left unsupervised or only partially supervised for long periods of time. Liquid crystal displays are far safer, offering far less of a fire hazard.

A facet of liquid crystal displays which is sometimes exploited is the ease with which display segments of practically any desired shape or size can be produced. The guise in which this most often appears is the pseudo analogue display.

Although digital displays have advantages in terms of accuracy and lack of reading error, there are certain applications (notably vehicle displays) where they have proved to be less than 100 per cent effective. The problem seems to be that it takes time to read a digital display, even a large type, with a consequent break in concentration. After a little familiarisation with an analogue display it can be read literally at a glance.

Pseudo analogue displays can take many forms, but the basic idea is to have a normal analogue scale with a series of pointers along the scale. By activating the appropriate pointer the requried reading can be generated. Note that this is not a genuine analogue display in that there is only a limited number of pointer positions available, whereas with a true analogue display an infinite number of positions is possible.

As far as I am aware there are no 'off the shelf' pseudo analogue liquid crystal displays available, not even in the form of a simple bargraph type. Companies such as Epson (of printer fame) offer a custom display service to OEMs, including the 'black-shutter' range, some of which will operate over an impressive temperature range of −30 to +80 degrees centigrade, and are primarily aimed at automotive applications. These displays use conventional guest-host principles, and consist of a black panel with segments which become transparent when activated. They are used with backlighting to offer a high contrast of 16 to 1 or more with a wide viewing angle.

LARGE DISPLAYS

In the past it has been normal for lap-held computers to have displays which provide something like two or four lines of forty characters per line, and while these are quite usable in many applications, such a small display has severe limitations and is often difficult to use. Recently introduced lap-held machines have often been equipped with much larger displays, and liquid crystal types offering the full 640 x 200 high resolution IBM mono graphic mode are now produced.

Photo.2. *High contrast black shutter l.c.d.*

The first high resolution displays were not well received by the computer press, and the machines that used them achieved only limited sales success. Things move on, and the latest displays have been improved by the use of anti-glare treated polarisers, and a new development from Epson is the use of s.t.n. (super-twisted nematic) technology. With displays of this type the 90 degree twist of a standard twisted nematic display is increased to 180 degrees or more, and the polarisers provide a bifringence effect rather than a shutter type. The practical result of this is an improved contrast ratio of 4.5 to 1 or more, but with a reduction in the response speed (about 300ms at room temperature). As these displays are intended for word processing and the like rather than space invaders this reduction in speed is acceptable.

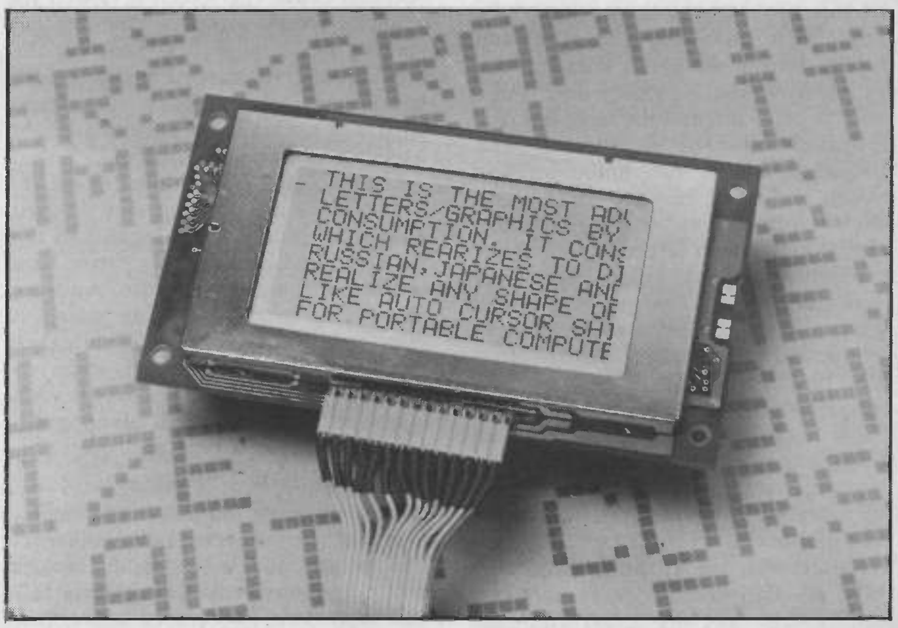

Photo.1. *EG 2201S–AR 128×64 dot graphic module*

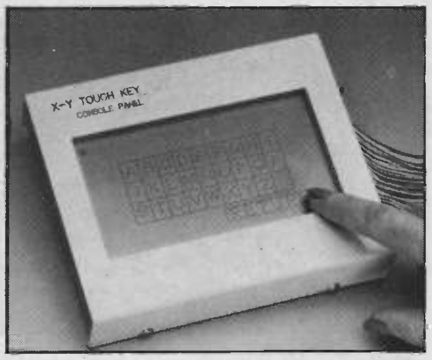

Photo.3. *Graphic l.c.d. with X-Y touch key overlay*

For battery powered portable equipment large liquid crystal displays are a very attractive proposition, with the Epson EG-7003 l.c.d. module, for example, having 640 x 200 dot resolution, a size of 290mm x 154mm x just 11.5mm thick, a 266 x 119mm viewing area, and a typical supply current of only 20mA. No current cathode ray tubes offer a similar display area together with such a small overall size and low power consumption. The EG-7003 is an STN display which is available with either silver or yellow background colour – TN types are grey/green in colour. Special driver devices are available for these complex liquid crystal displays, and the latest idea from Hitachi is a driver device designated the HD6345 which provides software compatibility with the 6845 CRT controller chip (as used in the IBM, BBC, and Amstrad computers amongst others).

TELEVISION

So far in the UK miniature television sets with liquid crystal displays have failed to make much impact, but it is early days yet and they could well turn out to be the next electronic 'craze' product. To say the least, there are problems in producing a liquid crystal display having suitable characteristics for television use. Response time is one obvious problem, and the large number of pixels required is another. The resolution of the 625 line television system justifies the use of around 500,000 pixels, but with a miniature television having a screen size of about two inches (diagonally) far fewer pixels gives acceptable picture quality. Current liquid crystal screens use resolutions from 15290 (139 x 110) to 52800 (240 x 220) pixels. This still leaves massive problems to be solved.

The screens use a system of multiplexing, and it is not that difficult to produce a complex rows and columns type display. In its most basic form the rows electrodes are placed on one glass substrate with the columns electrodes fitted on the other. A more complex arrangement has the usual common electrode with the rows and column electrodes placed on the opposite face of the display. By activating each row in turn, and then activating the required pixels in that row by driving the appropriate column inputs, a process which has strong similarities to a standard television scanning process is produced. The problem is the relatively short time during which each pixel is addressed, and the consequent low contrast of the display.

Epson's solution to the problem is to use a system called 'active-matrix addressing', and with this method some active circuitry using t.f.t.s (thin film transistors) is an integral part of the display. The general idea seems to be to have the scanning signals activate transistors which drive each pixel cell for the amount of time needed to give a good contrast display, rather than just for the brief period when the scanning signal addresses a pixel. The results are certainly impressive, and the picture quality is about as good as the small picture area permits. The screen area of these sets is perhaps rather less than one might expect, and it has to be remembered that screen sizes are always the measurement from corner to corner, not the screen width. Thus a two inch screen actually measures only about 1.6 by 1.2 inches, which is only about 1.9 square inches. The 2.7 inch screens fitted to some of these televisions actually gives a screen area not far short of double this (about 3.5 square inches).

The screens of all these televisions are minute by the standards of conventional sets, and even by normal portable standards, but they are intended for viewing distances of only about 300mm and give quite good results when used in this way. The screens are of the backlit variety, and normally use ambient light as the light source although electric backlights are often available as an optional extra. The screen is viewed via a mirror which provides a convenient viewing angle, as well as enabling the area around the screen to be a dark background, even though the screen itself will normally be against a bright background (the light source).

Liquid crystal colour screens have yet to appear in the UK, but they do exist already in products for Japan and the USA, and will presumably arrive here in the not too distant future. A colour display is produced using what is effectively three sets of cells with each one fitted with a minute red, green, or blue colour filter. In other words what is really just the standard RGB approach applied to the new type of display.

THE FUTURE

It seems a fair bet that liquid display crystal devices will continue to get bigger and better, and will steadily replace c.r.t.s, perhaps even appearing in full-size high definition colour sets before too long. C.r.t.s have reigned supreme for a great many years and they are certainly well overdue for replacement by a modern high-tech display. Improvements in portable television displays and computer displays seems to be a more likely development in the short term, with perhaps a high resolution multicolour graphics screen being the obvious next stage. The problem of limited lifespan is less of a drawback in applications which would conventionally be handled by c.r.t.s, since the latter have similarly restricted lifespans.

Liquid crystal displays have achieved little success in test equipment such as oscilloscopes, where they lack compatibility with the standard type of circuitry due to their slow response speeds. They are better suited to applications such as digital storage oscilloscopes, and have already appeared in such instruments. Perhaps low cost instruments of this type will eventually be developed, together with inexpensive circuitry to enable standard liquid crystal graphics displays to operate in equivalents to conventional oscilloscopes.

There is an alternative type of liquid crystal effect known as the 'smectic' type, which exploits the temperature phases of liquid crystals. This effect can be used to produce displays which effectively have a memory, with the liquid crystal material being electrically heated to enable the required display pattern to be set in the normal way, and then allowed to cool to 'freeze' this pattern permanently in place, or at least until the display is activated again. Whether this type of display has many worthwhile practical applications is debatable. Television sets which can be hung on the wall like paintings already exist, perhaps someone will make a fortune with smectic displays selling them as programmable pictures.

An interesting development in liquid crystal technology is the Epson 'touch key' display. This is basically a standard display with a membrane keyboard positioned over it, but the keyboard is formed from glass and a sheet of flexible transparent film with transparent electrodes. It does not therefore obscure the view of the display, and provides a touch screen for menu selection (or whatever). There are two types available; an 'X/Y' matrix type, and the 'A/D' variety which is read via an analogue to digital converter.

In the early days of liquid crystal displays there was speculation in the photographic press that they would eventually replace conventional mechanical shutters in cameras. This speculation was probably just grounded on the fact that Seiko produced camera shutters and also produced liquid crystal displays, rather than technical feasibility at that time. As far as I know there has yet to be a camera fitted with a liquid crystal shutter, and there are a number of severe problems that have to be overcome before such a set up could work satisfactorily. At present contrast ratios of about fifty to one or more can be achieved, but in order to give no significant light loss when taking the picture, and to avoid 'fogging' between exposures, a contrast ratio many times this figure would be required. Liquid crystal devices are slow even by mechanical standards, and shutter speeds of around 1ms look to be well out of range with current techniques. No doubt these problems can be overcome, but with so-called 'still video' cameras making rapid progress, the liquid crystal shutter for conventional cameras could be irrelevant before it becomes a reality. Still, it is an example of the sort of application where this technology could suddenly take over, and liquid crystal technology is not necessarily limited to display applications. PE

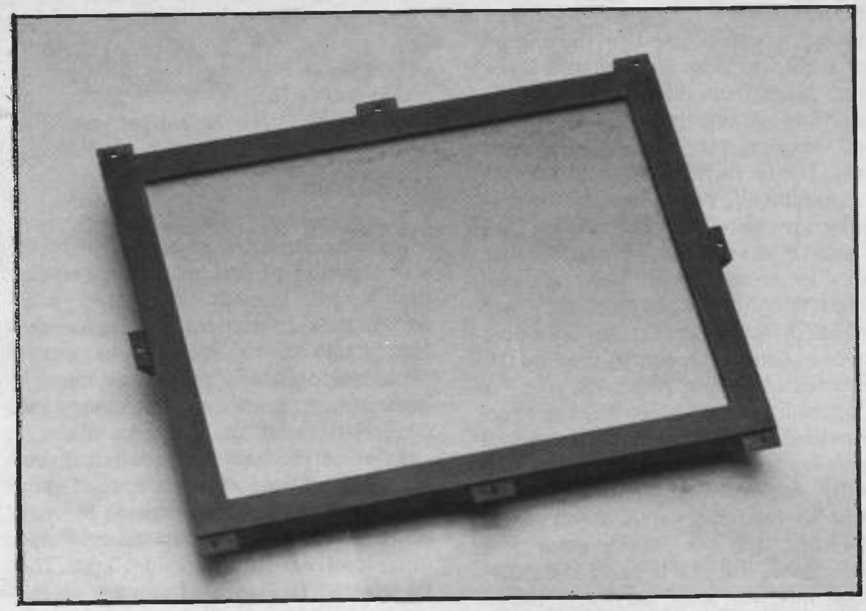

Photo.4. *EG8001$-AR 640×400 (80 characters ×50 lines) super TN graphic*

TECHNOLOGY FEATURE

MICROWAVES

PART TWO – BY ANDREW ARMSTRONG

Whats cooking in technology today?

CONTINUING from last month, we now take a close look at more applications of microwave technology.

Doppler radar also has many applications requiring less precision than previously described. Traffic lights used on roadworks are increasingly fitted with doppler radar to detect the approach of vehicles. There is then no problem with stationary objects being falsely registered as waiting vehicles.

The doppler modules used are not direction sensitive, and the control units seem to be fitted with a counter which changes once a few vehicles are waiting. On an otherwise empty road, the lights can sometimes be induced to change if one reverses a little and approaches the lights again a couple of times.

The limited beamwidth of the doppler module prevents it from falsely triggering on vehicles passing the other way, so long as it is angled correctly.

The other application of doppler radar is intruder alarms. Radar modules for this purpose are very simple, and generally use a gunn diode for transmitting. A small amount of transmitter power is leaked through to the receiver and mixed with the reflected signal to form a beat frequency. If the intruder could move at the speed of an elderly snail, he might avoid detection, but in general these types of alarm are effective and reliable.

COMMUNICATIONS

For some years microwaves have played a major role in communications, and it is a role which is growing in importance. The glamour industry at the moment is satellite television, but Telecom were using microwave links to carry calls before they were split from the GPO.

The Telecom trunk network traffic is currently split approximately equally between microwave links, coaxial cables, and optical fibres. It is expected that both the microwave and optical fibre shares will expand at the expense of coaxial cable.

The microwave links operate between Telecom towers, and are now mostly digital.

4GHz and 6GHz bands are used, with bandwidth and power depending on the application. An analogue system would use 18MHz for a 960 channel link, or 19MHz for an 1800 channel link. The small difference in bandwidths is due to the supervisory channels and the guard bands. For these types of link, 10W transmitters are used, which means that 7.7W reaches the antenna after losses.

In the case of a digital system used to transmit a television signal, a digital information rate of 140Mbits/second is needed. The r.f. bandwidth used depends on the modulation scheme used. Four phase modulation needs 134MHz, while 16 level q.a.m. (quantised amplitude modulation) needs 34MHz, and 64 level q.a.m. needs only 6MHz. This last is down almost to the analogue bandwidth, and the obvious question is "Why not use analogue?" The answer is that using a level quantised signal the original can be reconstituted exactly unless interference equivalent to at least half a level occurs.

Of course, the more levels of q.a.m. that are used the less interference and fading can be tolerated. This is a fine example of the tradeoff between bandwidth and transmitter power which is so often relevant to microwave communications. Even so, the transmitter powers used in the digital links are lower than in analogue links. Powers range from one to four watts.

Not only are television signals routed round the country via the Telecom towers, but feeds from different regions are automatically switched at the towers.

Telecom also provide short haul microwave links, for example to office blocks in areas where there are not enough telephone lines, and they will provide private circuits, for example where a computer centre has to be connected to several major users.

Communication to North Sea oil rigs is provided by using very high powered microwave transmitters and high gain aerials, and relying on tropospheric scatter to feed through a small signal even when it is over the horizon. For this purpose, the 2GHz band is used.

Last but not least on the Telecom front, about half the transatlantic phone calls are not via satellite. There is generally no distinguishable difference between satellite and undersea cable links, but sometimes there is an echo on the satellite link due to the greater delay.

Higher powers and different bands are used for satellite communications. Uplinks on the 14GHz band run 500W and 1000W and downlinks on the 11GHz band use 10 to 20W.

The subject of satellite television has recently been covered in Practical Electronics and it needs no more exposition here.

INSTRUMENT LANDING SYSTEMS

The availability of a highly directional beam makes microwaves ideal as a means to detect and control aircraft position on approach and landing. Lower frequency systems can suffer from the effects of reflection from nearby buildings, etc.

At present a doppler system is being considered, in which a moving and a fixed source of the same microwave frequency are provided at the runway. The doppler shift of the moving source relative to the fixed one will be proportional to the cosine of the angle between the aircraft and the line of the moving source. The moving source is in fact a commutated line array, which produces the same effect.

The use of two arrays at right angles can provide azimuth and vertical information.

Britain's first microwave landing system (m.l.s.) is on trial at Heathrow Airport. The system, manufactured by Plessey, will initially be used only on one runway, and will be backed up by the present instrument landing system. The International Civil Aviation Organisation intends to make m.l.s. its preferred standard by 1988.

A major reason for this is to reduce the problems of reflection from surrounding buildings and hills which bug ordinary ILS. Some five per cent of the world's airports cannot use the present type of ILS at all.

HAZARDS

When microwave cookers were less common in Britain than nowadays, there was a period of serious concern about the health hazards associated with microwaves. In particular, there was the fear that microwaves could cause cataracts, and that there was enough leakage from some domestic microwave cookers to constitute a serious risk.

Most of the anxiety has died down, but some information has emerged. Any heating of the eye can increase the risk of cataracts, as can exposure to any ultraviolet or even far blue light. The most plausible cause of damage to the eye by microwave radiation was through simple heating. Any given 'safe' exposure limit for the whole body might be too high for the eye, which has blood supply only to the periphery, and consequently cannot dispose of excessive heat rapidly.

Heating of body tissue is the only scientifically accepted cause of health damage due to exposure to microwave radiation. There has, however, been some speculation that damage can occur even at exposure levels too low to cause significant heating of the eye, let alone any other part of the body. How this could happen is not clear, because we know from quantum theory that the frequency is far too low to cause ionisation, and hence to induce any known chemical change.

Is this a case of popular myth without any factual basis, or is there some subtle but as yet undiscovered effect at work? Evidence in support of the latter comes from Russia. The Russian limit for exposure to microwaves is set at $10\mu W/cm^2$, while in Britain it is $10mW/cm^2$. Perhaps they know something we don't. On the other hand, there has not been a rash of illnesses attributed to microwave exposure now that microwave cookers are ubiquitous.

You must make up your own mind, but you are well advised not to peer too closely into the microwave cooker while it is running, just in case . . .

SHARP END TECHNOLOGY

At present, work is going on to combine microwaves and optics, particularly in the field of phased arrays. The idea of a phased array is to have an antenna consisting of many elements, each having a carefully controlled phase and amplitude response to produce whatever directional characteristics are required. This is of particular interest for military radar systems, such as early warning radar. For general surveillance, a wide beamwidth is needed, but for tracking a target once it has been found a narrow beamwidth is needed.

If a phased array could be made with all its elements rapidly adjustable under computer control, then it could both scan and track. At present separate radars are needed for this purpose.

In order to move towards this ideal, an array of individual transceive elements is used, and in recent research the local oscillator to each one is a laser signal supplied via an optical fibre. The laser signal is modulated with the microwave local oscillator signal, and the phase of the signal to each element may be adjusted by controlling the optical path length. An optical i.c. would perform this function.

The mixer which responds to the optical signal would be fabricted using gallium arsenide. This is optically responsive and is suitable for microwave frequencies. The light generates electron hole pairs in the active area of the mixer, which would be a schottky type device.

Gallium arsenide is also used to make experimental microwave integrated circuits. The undoped gallium arsenide forms a good microstrip substrate, and the devices are doped into it using ion implantation. The active devices and the matching elements are all on the same chip. One thing that has held this development back has been the difficulty of producing an adequately pure, monocrystalline gallium arsenide substrate with few enough defects to be usable.

An exciting possibility for the future is the use of conformal arrays, taking the planar aerial array one step further. Such devices are already under development for military use, but in the future it may become possible to mould an aerial into the shape of a car roof, and control its beamwidth and direction electronically to track a satellite as the car moves. Telephone calls could be sent and received directly from the satellite, on the move. Eat your heart out, cellular radio.

On a more down to earth front, there is a lot of interest in 60GHz at the moment, both for military and civilian uses. The great advantage of this frequency is that it is absorbed heavily by oxygen, so that the range is limited. This is ideal on a battlefield when you do not want your short range communications to reach the enemy. It could also help with the problem of overcrowded cellular radio, by permitting much smaller cells, and much closer geographical reuse of each frequency.

Development is proceeding. Will we have (or need) microcellular radio, or will this band be allocated purely for military uses?

In any event, there is a lot happening in the field of microwaves. Is it any surprise that job ads for microwave engineers normally quote good salaries? PE

THE BEEB BRAKE

BY J. NOLAN

A slow-down device for the BBC

COMPUTER BRAKE

THE circuit shown in Fig. 1 allows the slowing down specifically of the BBC Computer, although it should be compatible with most systems with a clock output and interrupt request input. The circuit has numerous uses, which include a device to slow the computer down when arcade type games are being played. This allows the computer to be slowed down to a set speed at crucial moments and consequently makes negotiation of the game dramatically easier. The circuit shown in Fig. 3 allows control of the circuit from a non-latching type switch which could be fitted near to the fire button in the joystick, and consequently the circuit can be easily controlled in conjunction with the rest of the game.

Other uses include the slowing down of programs and of devices connected to the I/O port. This allows each step of the program to be analysed. I have also found it extremely helpful in listing programs and, although the speed of the listing is software variable on the BBC Micro, I found the $\overline{IRQ}$ device very useful for controlling listings speed, as unimportant lines can be listed quickly and lines of greater importance can be listed slowly or stopped.

As can be seen, the circuit is extremely easy to build and could be fitted inside the computer itself. Connections for the BBC micro are shown in Fig. 4; however, if the circuit is fitted internally the connection wires could be soldered to the relevant points. The interrupt circuit shown in Fig. 1 consists of a dual retriggerable monostable (IC1), but as only half is used there is plenty of room for modification. It should be possible to use most monostables in the circuit, but the timing components C1, R2, VR1 and VR2 may have to be changed in accordance. IC1 is triggered on the positive-going edge of the clock signal and creates an interrupt of length determined by the timing components and position of S2, which switches either the Q or $\overline{Q}$ outputs of the monostable to the $\overline{IRQ}$ input. As can be seen, the system is based on the generation of interrupts, which temporarily divert the microprocessor.

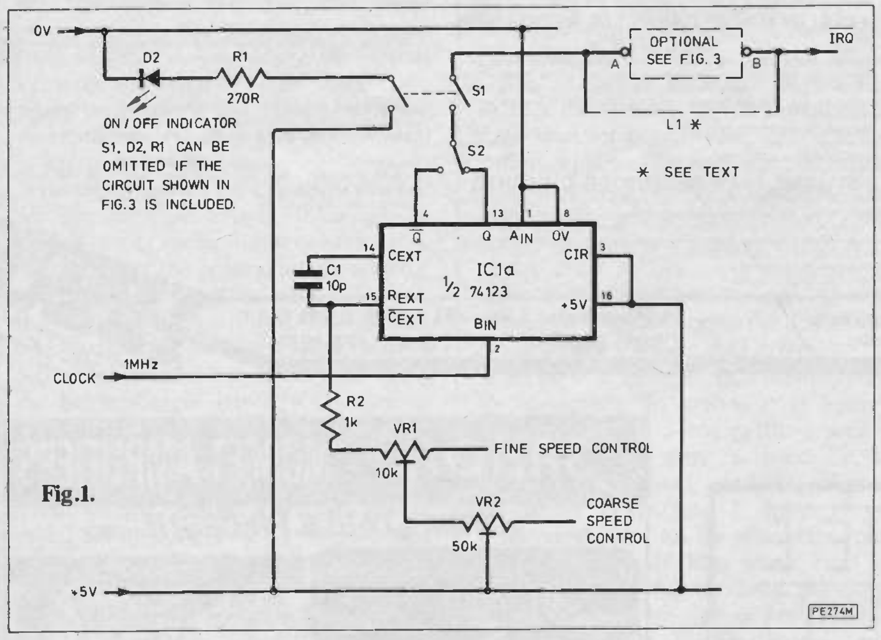

Fig.1.

The circuit shown in Fig. 3 allows the interrupt circuit to be used in conjunction with a fire button type switch. This switch S3 is debounced by IC2a and associated circuitry, IC2a being a Schmitt trigger NAND gate. The output is then fed into IC3a (a p-type flip flop) which is connected to act as a divide by two counter. The output from this is then fed into IC2b which enables the interrupt signals from IC1 to pass through to the computer. If used this circuit should be placed between the points indicated on Fig. 1, e.g. A and B, and the link L1 removed.

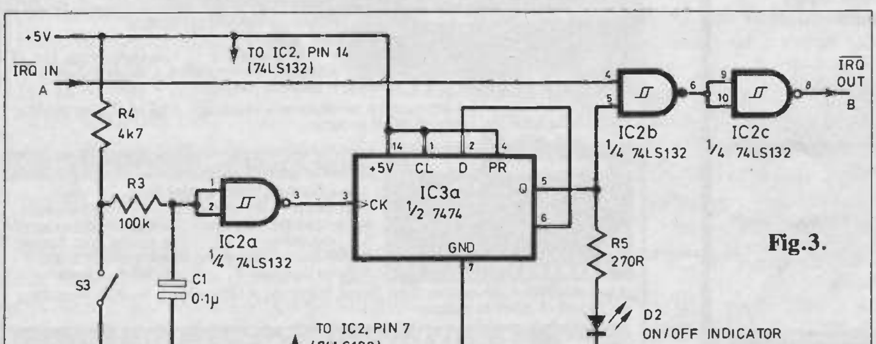

Fig.3.

The system has worked with all the programs I have tried it on, including Revs, along with numerous other machine code and BASIC programs.

To save on IDC connectors, and as one connection only is required on the I/O port (+5V), it is possible to use a crimp terminal (Fig. 2). It is then advisable to mark the connection point on the I/O connector, to avoid any confusion.

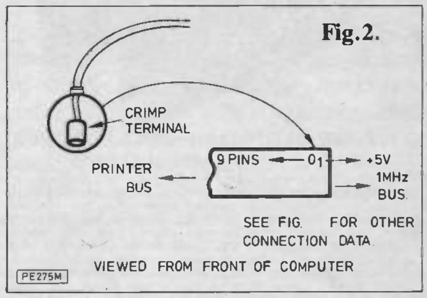

Fig.2.

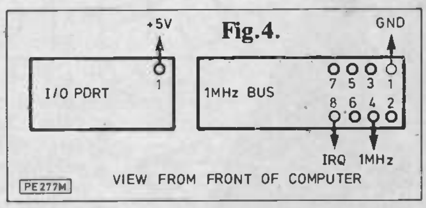

Fig.4.

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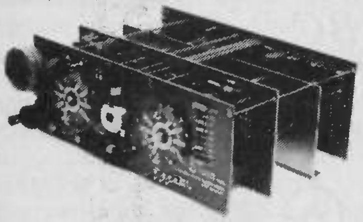

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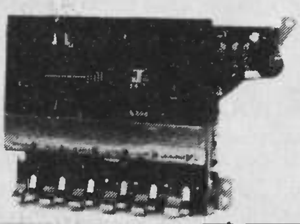

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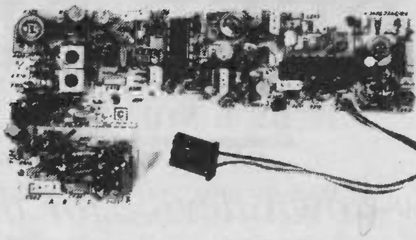

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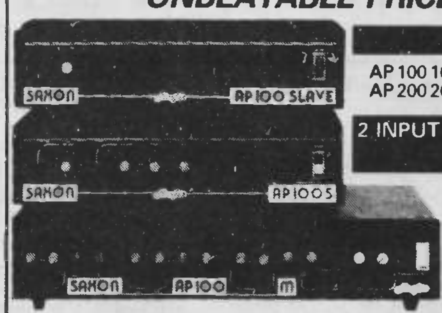

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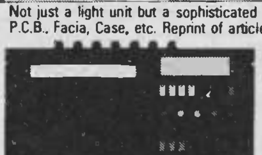

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INDUSTRY NOTEBOOK

Efficiency vs. employment and labour productivity

REPORT BY TOM IVALL – PE's NEXUS

INFORMATION storage is at the very heart of digital electronics and communications. With the technology still developing it's not surprising to find that the business of making and selling places for bits to come and go is in a state of flux. Mergers, takeovers, joint ventures and other deals are the surface phenomena of the underlying economic mechanisms of supply and demand still working themselves out.

At the moment, for example, there is a noticeable move among US companies to pull out of semiconductor memories. This is part of the general semiconductor recession, of course. So we see Fujitsu, the Japanese electronics firm which concentrates on memory chips, buying 80% of Fairchild Semiconductor from the Schlumberger group, its American owner. Apparently Fujitsu will be combining this acquisition with its existing US and European operations. Schlumberger, whose main business is in oil prospecting and instrumentation and, incidentally, owns Solartron in the UK, is letting Fairchild go at a very low price which will result in a £140 million loss on the deal.

In optical information storage there has been a welcome agreement between several big companies to standardize the basic specifications of a family of 130-mm optical disc drives and media with the idea of assisting interchangeability. The agreement is based on standardization discussions on cartridges between the USA, Europe and Japan. Along with the ISO (International Standards Organization) the firms involved are the Philips and Du Pont Optical Company (Netherlands), Alcatel Thomson (France), Laser Magnetic Storage International (USA) and Sony Corporation (Japan).

Hewlett-Packard have been introducing some new technology into their magnetic disc stores. They have just brought out a family of 8-inch Winchester disc drives in which the magnetic recording surface is a sputtered thin film. Recording density of bits per unit area is increased by this production technique as it allows the head to be closer to the medium, thereby reducing the space needed for a bit to be stored.

Memorex is a well known name in magnetic storage tapes and discs. In recent years it has been a subsidiary of Burroughs, the computer firm, which last year acquired Sperry (as I reported in September 1986). But as part of the general rationalization of Burroughs and Sperry – which incidentally now have the single new name of Unisys – much of Memorex has been sold off to a group of its own managers and a New York financier, Eli S. Jacobs.

The Memorex activities disposed of include its sales and service organization for computer peripherals, its communications engineering and manufacturing, and its media products business. This little lot, which has about 6000 employees and an annual turnover of about £650 million, will continue to trade under the Memorex name. Unisys, though, are holding on to the design and manufacture of large disc drives.

So we now have this new name Unisys to remember. To arrive at it Sperry-Burroughs held a competition among employees and were assisted by an 'identity consultant' called Anspach Grossman Portugal. I haven't yet discovered what an identity consultant is, but it sounds like some kind of psychotherapist for mentally disturbed companies. To me the name Unisys is almost abstract – featureless and forgettable. But perhaps this is appropriate for organizations which get together not because they like each other as people but defensively, on behalf of shareholders who are not really interested in the actual work that creates the money. No wonder they need help for an identity crisis.

Manufacturing industry, which of course includes electronics production, now provides only 21% of all employment in the UK. Sir Terence Beckett, who retired last year from the director generalship of the CBI (Confederation of British Industry) thinks this figure is going to fall even further. "There are a good many plants which could work without any people at all" he said recently. "Even a flourishing manufacturing industry will employ fewer people." The CBI being an association of employers, Sir Terence should know.

Over the past year or so, manufacturing industry has been shedding jobs at a rate of about 10,000 per month. According to the Institute of Manpower Studies a further 100,000 jobs will be gone by 1990. This process, of course, is exacerbating unemployment generally, which is currently over 13% of the total working population of about 28 million people.

Opinions differ on the cause of unemployment in the British economy. Some say that a free market economy cannot be relied on to deliver in this respect. Their opponents say the free market system would provide enough jobs if it were not restricted by political/social considerations.

But all are agreed that unemployment really 'took off' in the mid-1960s due to structural changes in British industry. Among these changes was modern automation, with electronics providing the information processing between transducers and actuators and better overall control of factories through computer systems (computer integrated manufacturing). The effect of this electronics technology was certainly to put many people out of work. Last year the Policy Studies Institute estimated a loss of 87,000 jobs over two years.

But more often than not the primary purpose of this new automation has been to improve the speed, reliability or accuracy of processes, or the utilization of capital or materials, to give better and cheaper products. Human beings have been displaced, not so much because of their cost in wages but because of their limitations as instruments of production. This could be socially beneficial if it also frees people from the degradation and tedium of being servants to machines – though they could just be displaced into other forms of industrial discipline in which they become servants to systems.

The term 'labour productivity', well known as a measure in business economics, could acquire a somewhat different meaning through the march of electronics. Hewlett-Packard have just introduced a new electronic patient monitoring equipment for maternity hospitals. Called an Obstetrical Management System, it allows a single nurse to monitor physiological variables such as heart-rate in up to nine mothers-to-be. In publicising this sytem H-P say that "this capability is a major step towards increasing productivity in the labour and delivery ward . . ." I must say I find the association of ideas in this techno-speak a somewhat chilling view of birth in an industrialized society. PE

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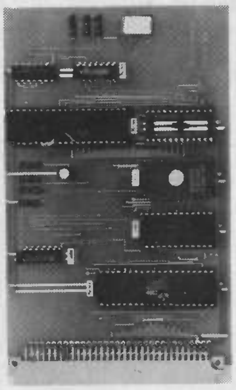

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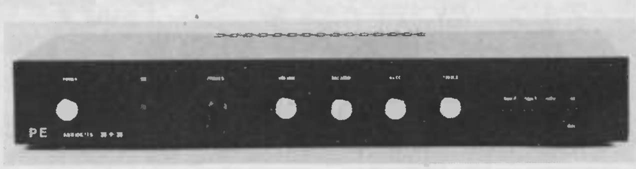

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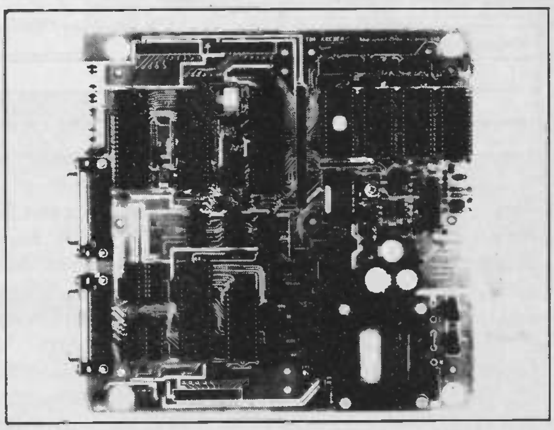

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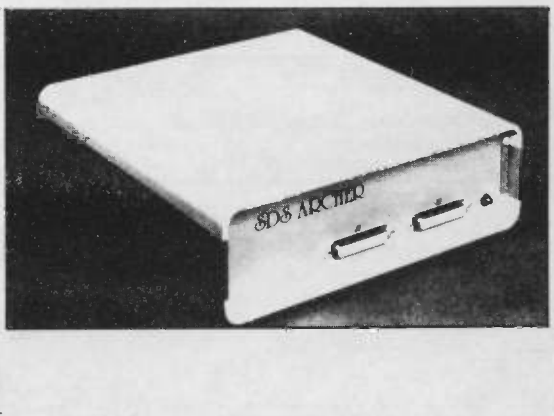

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29 Windsor