PRACTICAL

ELECTRONICS

DECEMBER 1988 · £1.25

SCIENCE & TECHNOLOGY

BUILD A MUSIC MIXER

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THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

PRACTICAL ELECTRONICS

PE VOL 24 NO 12 DECEMBER 1988

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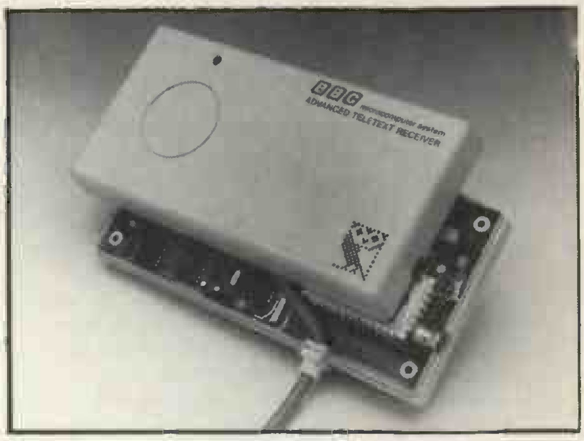

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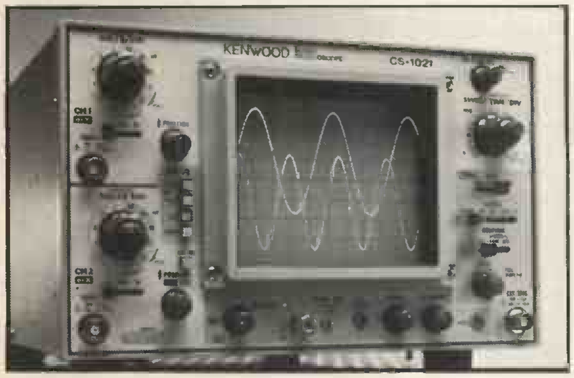

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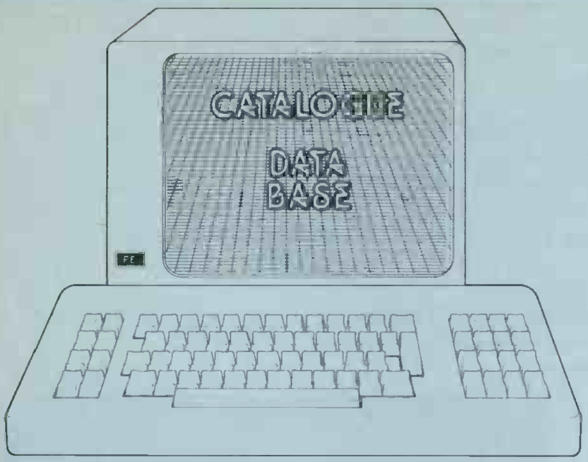
NEXT MONTH . . .

WE'VE SCINTILLATING FEATURES TO SPARKLE-UP THE FESTIVITIES

★ A SHERLOCK HOLMES MACHINE ★ A CHOICE OF SEASONAL SPANGLERS ★ RAILWAY ELECTRONIC SIGNALLING (sorry the postal strike didn't allow it this month – or the Digital Multimeters feature, which is being rescheduled) ★ AND OF COURSE WE'VE OUR REGULAR GIFTED AUTHORS WITH THEIR TOPICAL NEWS, VIEWS AND FEATURES.

ADD OUR JANUARY 1989 ISSUE TO YOUR LIST OF LONGED-FOR PRESENTS ON SALE FROM FRIDAY DECEMBER 2ND

THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS



We have recently received the following literature:

Cricklewood have sent us their superb new catalogue. It's their 14th edition and is by far the biggest they have ever published. (But why has Crickles the cat lost her portrait on the cover?!) 100 pages are filled with information, prices and pictures of **hundreds of new items**, and many prices have been reduced. If you are looking for a wide variety of good quality electronic components, you should **definitely add this catalogue to your library**. It costs only £1 including post and you'll soon recoup this if you take advantage of the £10 of discount vouchers included. You even get a prepaid envelope for your orders. **Cricklewood Electronics Ltd., 40 Cricklewood Broadway, London NW2 3ET. Tel: 01-452 0161.**

Greenweld's 1989 catalogue of electronic components will definitely be of interest to PE readers. It has over 100 pages and is the biggest they've produced. It contains an enormous range of components, in their words, 'everything from the humble resistor to complex audio mixers and oscilloscopes!' It will cost you £1, but you'll soon recoup that through the bargains on offer. Your Ed first met Greenweld's director Peter Green many years ago and knows he ensures **his company offers the best in service and quality. Greenweld Electronic Components,** 44 Millbrook Road, Southampton, SO1 0HX. 0703 772501.

Tandy's annual catalogue has been released covering their **1989 product range**. Drop into any of Tandy's numerous stores and **pick up your own FREE copy.**

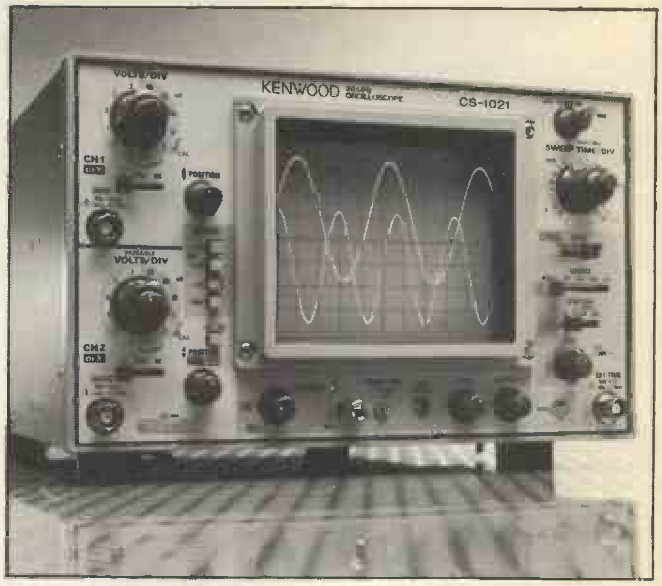
Cooke International are specialists in **second user test equipment** and have a very wide range of low cost gear available, as their catalogue shows. They also have a 'growing pile' of spare part equipment that they regard as uneconomic to repair commercially but which might present an interesting challenge to devoted diy-ers. They continually update their stocks and information so its well worth while getting your name on their mailing list. **Cooke International,** Unit 4, Fordingbridge Site, Main Road, Barnham, Bognor Regis, W. Sussex, PO22 0EB. 0243 685111.

Hitachi's 14 page brochure on **gate arrays** will be of interest to those involved in semicustom products and other applications where microprocessors may not be appropriate. They have also published a short brochure describing the HD81801 ADPCM and its applications in systems requiring **digital speech storage,** playback or synthesis. **Hitachi Europe Ltd**, 21 Upton Road, Watford, Herts. WD1 7TB. 0923 246488.

STC have a new 32-page brochure available on the **IBM-compatible Audiocard 300E.** The publication highlights the many features of this **unique speech recording** and play facility for PCs. **STC Instrument Services**, Dewar House, Central Road, Harlow, Essex, CM20 2DF. 0279 641641.

Techstyle have introduced a brand new product range covering integrated **home storage systems for sophisticated hifi users.** The systems have been designed and manufactured in the UK and individually provide high quality storage for cds, tapes and videos. They also have a **good selection of portable cases** for many other purposes, and aptly named their Clik!Case range. Their catalogue beautifully illustrates the ranges and some of their applications. **Techstyle Products Ltd**, 2 Bath Road, London W4 1LN. 01-747 0392.

WHAT'S NEW



Kenwood mixed

Two 20MHz channels are available on the new Kenwood CS1021 oscilloscope. Sensitivity ranges from 2mV up to full bandwidth and 1mV up to 10MHz (–3dB). An accuracy of 3% is quoted for both vertical and horizontal amplifiers.

Sweep speed is continuously variable between 0.5 μs/div and 0.5s/div with a further 10-times sweep expansion available which permits detailed observation of a portion of a complex waveform.

Triggering sources available are Channel 1, Channel 2, line, external and V mode. When V mode is selected the trigger source is automatically selected according to the vertical axis mode. Thus for CH1 or CH2 mode the signal inputs to these channels become the trigger source. In the ADD mode the sum (or difference if CH2 is inverted) becomes the trigger source. The ALT mode is particularly convenient since each channel input then becomes its own trigger source.

The scope uses a large (150mm rectangular) high intensity crt which ensures a bright display and high resolution, while having the added advantage of eliminating parallax errors. Other features include a convenient X-Y display for measuring phase differences and a Z input for intensity modulation.

The CS1021 costs £319 plus VAT, and is supplied in a compact package weighing 8.4 kg with dimensions of 260 x 160 x 400 mm. A padded carrying case is available as an optional extra.

Contact; Thurlby Electronics Ltd., New Road, St. Ives, Huntingdon, Cambs. PE17 4BG. Tel: 0480 63570.

Scoping at 60MHz

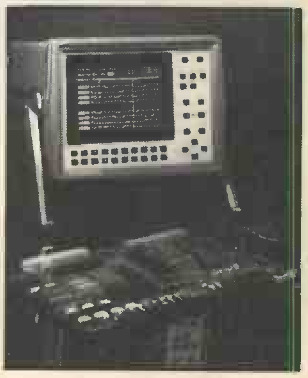
Very much for professional technicians, the new HM604 scope from Instrumex features a dual-channel measurement amplifier to ensure faithful waveform transfer characteristics, and an analogue output for connecting multimeters or counters. Using Y-axis magnification of x5, the instrument is able to display signals as low as 0.5mV.

A delay line has been included for observing the leading edge of a signal, together with a calibrated sweep delay mode allowing waveform sections to be magnified 1,000 times.

An after-delay trigger has been provided which ensures that displays are stable and measurements of pulse trains, or asynchronous signal sections and bursts, are jitter free. To further enhance display quality, an active tv-sync-separator has been included for video frame and line frequencies.

Included with the scope are two switchable probes a trimming tool for the probes and dc balance, and a line cord.

Contact: Instrumex Ltd, Dorcan House, Meadfield Road, Langley, Berks. SL3 8AL. Tel: 0753 44878.



Multirooming Revox

Have you ever dreamed of Revox quality in every room? Dreams can now become reality for Revox have produced the first true off-the-shelf multi-room hi fi system.

Based on either the B285 receiver or the B250/260 amplifier and tuner the system maintains the normal high controllability of all Revox products, with up to three sets of speakers (two passive and one active), connected directly to the amplifier. Each successive room in the building – as many as required – is also allowed access to the main Revox system. The simple addition of a B209 room controller per room, amplification and speakers (esoteric or mundane, according to choice) will allow local control of volume tone and balance, while still permitting selection of choice ie, cassette, cd, tuner etc, in the main system. This source may be the same or *different* to the source being listened to in the main room.

Also imminently expected is the introduction of the B200 controller/timer which will allow full switching of video sound and pictures throughout the home.

All products, plus cables, connectors and advice are **available from:** F.W.O. Bauch Ltd., 49 Theobald Street, Boreham Wood, Hertfordshire WD6 4RZ. Tel: 01-953 0091.

Wakey tele-talky

Offering a good incentive not to oversleep, Goodmans have expanded their Quadro range of radio/television with the introduction of the Quadro 903 to which they have added a full alarm feature and led clock.

This new tv/radio/clock/alarm features a 4½ inch black and white tv, mw/fm radio with snooze sleep controls, plus battery back up to ensure the clock keeps time in the event of a power failure. Supplied with a 12 volt car battery lead, it's ideal for those in pursuit of the outdoors, on land or at sea.

For a retail price of around only £79.99, you can have the choice of waking up to tv, radio or buzzer.

The Quadro 903 is available from all Goodman's stockists, or in case of difficulty:

Contact: Goodmans, 2 Marples Way, Kingscroft Centre, Havant, Hampshire PO9 1JS. Tel: 0705 486344.

Miniature IR CCTV

A new, miniature, infrared cctv camera from Electro-physics is ideal for the inspection and study of semiconductor wafer defects, photographic darkroom monitoring, night surveillance and the detection of ir-emitting lasers etc. Features include a high sensitivity of down to 0.01 lux, and small physical size of only 8.59 x 3.94 x 2.7 inches. It weighs just 1.8kg.

The unit has a high resolution of 600 tv lines and provides a standard 1V peak-to-peak (75Ω) video signal that can be fed, via ordinary tv coaxial cable, to any 625-line monitor. The camera is fitted with a 25mm f1.4-f16 C-mount lens as standard but a range of close-up lenses is also available.

Other accessories include high-speed objective lenses, ir filters, and microscope adaptors etc.

Contact: Lambda Photometrics Ltd., Lambda House, Batford Mill, Harpenden, Herts AL5 5BA. Tel: 044 284 2450.

COUNTDOWN

If you are organising any event to do with electronics, big or small, drop us a line – we shall be glad to include it here. **Please note:** Some events listed here may be trade or restricted category only. Also, we cannot guarantee information accuracy, so check details with the organisers before setting out.

Nov 8–12. Electronics 88, Munich. World's largest trade fair for electronic components and assemblies. 01-948 5166.

Nov 29–Dec 1. DMC-PC. Drives, motors, programmable controllers etc. National Exhibition Centre, Birmingham. 0799 26699.

Dec 11. Satro Annual Computer and Technology Show. Music Hall, Aberdeen. 0224 273161. Satro, the Science and Technology Regional Organisation is a non-profit making organisation dedicated to supporting and enhancing science and technology education. Profits from the show will be devoted to developing computer and electronics clubs. **We hope it will be well supported.**

1989

Apr 5–6. Laboratory Science and Technology Show, Kelsey Kerridge, Cambridge. 0799 26699.

Apr 25–27. British Electronics Week. Olympia. 0799 26699.

UV PCB maker

Printing your own pcbs is simple with Mega's newly-developed low-cost ultravoilet exposure unit.

Moreover, it's a double-sided unit and has a working area of 51.5 x 37.0 cm onto which the sandwich of repro material, film and artwork is secured in positive contact by means of a powerful vacuum. Produced in a 'suitcase' design, the unit incorporates six 20W ultra-voilet tubes in both the lid and base. Those in the base are set behind a strong perspex screen, which represents the working area, while the lid contains a flexible film mounted on a rubber gasket to ensure a positive vacuum.

Controls for the exposure unit include a 7.5 minute solid-state timer, which does not need to be reset between exposures, and a switch to isolate the base tubes when only single-sided work is undertaken.

At its price level, Mega claim that the unit represents cost savings of around 50%, by comparison with others currently available.

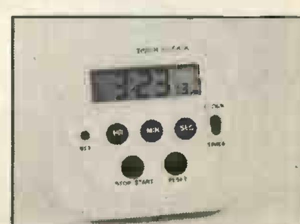
Contact: Mega Electronics Ltd., The Grip Industrial Estate, Linton, Cambs. CB1 6NR. Tel: 0223 893900.

Down time

There's a new lower cost led interval timer and clock that will help all concerned to "keep track of time", thereby avoiding costly encounters of the disaster kind.

Whether keeping appointments, timing meetings or catching that train or plane, Maplin's "Up-Down Timer Clock" should keep you on schedule.

At only £7.95 including VAT, and is available from Maplin by direct mail or from their nationwide shops.



Blank Ammo

The anti-copy battle rages on – the IFPI secretariat (international federation of phonogram and videogram producers) has issued another statement:

The House of Lords has delivered further ammunition in the record industry's battle for a levy on blank tape and recording hardware by severely criticising the ineffective laws which presently cover the home taping of records and tapes. In a message, which will carry strong reverberations for the Copyright, Designs and Patents Bill currently before the Commons, Lord Templeman said millions of breaches of the law were committed every year by those taping copyright recordings without permission or remuneration to copyright owners. He went on to pronounce that a law which is treated with such contempt should be amended.

Lord Templeman's remarks were included in the judgment of the House of Lords in an appeal concernng the marketing and advertising of double-speed twin tape recorders by Amstrad Consumer Electronics and Dixon the retailers. Although the Law Lords regretted that they were unable to allow the appeal under the law as it stands, they acknowledged the infuriating position that record producers were placed in under the present law and referred to levies on recording equipment and on blank tapes as being possible solutions to the problem.

The judgment must be seen as a clear message to the United Kingdom Trade and Industry Minister Kenneth Clarke to introduce a levy on blank tape and recording equipment. Although a feature of the Government's April 1986 White Paper, the levy has since been scrapped in a complete reversal of documented government policy. The inability of the Law Lords to uphold the BPI's case is a direct result of the inadequacy of current Copyright Law to deal with the developments of new technology. It is to be hoped that the Government will take note of Lord Templeman's statement that:

Parliament could place limitations on the manufacture or sale of certain types of tape recorders and could prescribe notices and warnings to be included in advertisements.

BPI's and other companies' decision to initiate this appeal will have served a useful purpose in providing the Government with a timely reminder of the grievances of record producers. The record industry wholeheartedly concurs with the Law Lords that home taping cannot be prevented and is widely practised; the only solution is new legislation incorporating a levy on blank tape and recording equipment.

Further to my Editorial comments in the July '88 issue, in which I also stated that I did not condone home copying, some readers have made what appear to be valid comments.

The gist of the comments is that when a recording is purchased the readers wish to be able to play it not only on in-house hifi equipment, but also on cassette equipment. Since the readers are not prepared to purchase the same music in all its forms, cd, lp, tape etc., the only alternative is to copy from a disc original onto cassette tape for use in cars and on personal stereos.

Ed.

Can the law save the recording industry from the pirates?

Thatching Teleview

A recent ceremony in Singapore marked the joint r & d achievement between Singapore Telecom and GEC-Marconi in the development of Teleview, the world's most advanced photo-videotex system. Mrs Thatcher took part in a joint demonstration of the Teleview System to civic leaders and ceremony guests, and spoke on behalf of Britain's participation.

Teleview will be the world's first hybrid Videotex system, harnessing both telephone and tv broadcasting technology.

An electronic information system designed for easy use by any telephone subscriber, it offers two-way, fully-interactive information retrieval. The system selects information pages from a host of computers and displays them on specially adapted television sets connected to home telephone line. To use the service, the user first calls the Teleview computer, using a keypad. He then keys in his selection and the requested information is encoded and "returned" via the television channel. The adaptor picks up the information from the tv antenna, decodes the information and displays it on the television set.

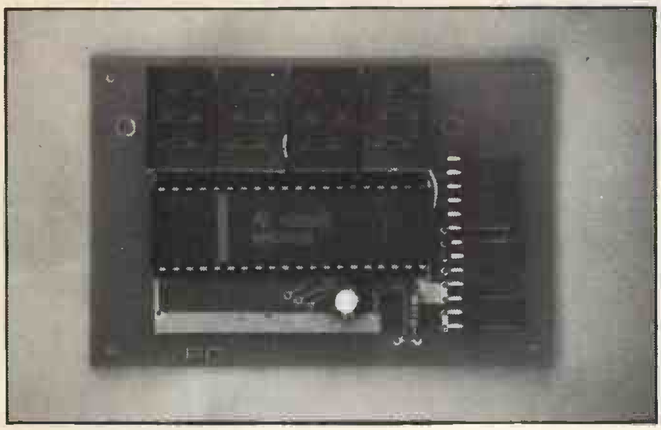
A field trial involving 450 business participants will begin shortly and residential trials will take place in 1989.

LCD Tai-in

There was a time when the cost of producing goods in Japan gave the Japanese a favourable market edge over manufacturers of similar products in other countries.

Now the strong Yen and the high cost of Japanese living is affecting at least one major manufacturer. Hitachi have announced that they are transferring production of their smaller lcd modules to a highly automated plant in Taiwan.

Although the lcd market has long been dominated by the Japanese, offshore manufacturers with low operating costs have been able to attack the low end of the market through aggressive pricing. Hitachi's move is intended to strengthen their position in the cost-sensitive market while maintaining their traditional commitment to quality. **Ed.**



Micro ledding

A new compact 57mm x 87mm unit simplifies the implementation of led displays on any microprocessor system. Only three outputs are required to control the display and just a +5V power supply is needed to drive the unit.

With 34 output ports available the unit is ttl compatible, and features four 7-segment 0.43 inch red led displays which are positioned to fit a standard bezel. The MM5450 display driver is utilised, featuring internal data latches, which relieves the host system from display memory and control duties.

Serial data transfer from data source to the unit is accomplished with two signals; serial data and clock, a data enable signal can also be used for multi-mode applications. Data is input to the unit in a serial form with a leading start bit followed by the serial data bits. The display is up-dated on the 36th clock pulse.

The unit can also be used as a general purpose output port, giving 34 output ports, which is extremely useful if your existing hardware system is running short of available output ports for your particular application.

For more details contact: J.P. Designs, The Old School, Prickwillow, Ely, Cambridgeshire CB7 4UN. Tel: 035 388 325.

CHIP COUNT!

This month's list of new component details received.

2322-640-6 series of ntc thermistors achieve closer tolerances and better stability than their predecessors. **(PL)**

CQY90A. High intensity infrared emitting GaAs diode for remote control and similar applications with 21mW radiant power – double that of its nearest counterpart. **(PL)**

IMS T800-G25S. 25MHz floating point transputer delivering a sustained performance of 2.9MFlops (millions of floating point operations per sec) when handling 32-bit calculations. A 30MHz version is planned for 1989. **(IN)**

LBG402, LBG403 series. Supertwist and double-supertwist lcds developed to produce high contrast displays with wide viewing angles at high multiplex ratios, and having 640 x 200 pixels each. **(PL)**

MC 68030. With a 33MHz clock speed this chip becomes the fastest general purpose 32-bit microprocessor on the market. **(MT)**

More information can be obtained from:

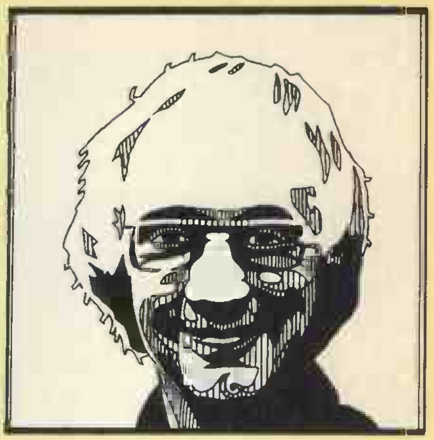
(IN) Inmos, 1000 Aztec West, Almondsbury, Bristol, BS12 4SQ, 0454 616616. **(MT)** Motorola Computer Systems, 27 Market Street, Maidenhead, Berks, SL6 8AE, 0628 39121. **(PL)** Philips Components, Mullard House, Torrington Place, London, WC1E 7HD, 01-580 6633. Also, **Mitsubishi** have announced from Japan that they have developed a single multi-function rom combining a 256Kbit one-time programmable rom (otprom) and a 16Kbit sram, but they have not told us the type number or distribution details.

NETTING CELLNET

By Barry Fox
Winner of the 1987 UK Technology Press Award

WE'RE NOT IN, EVEN WHEN YOU'RE OUT

Cellular radio – cellphones – were the hope of the UK consumer electronics industry, but who will answer the call?



Shock waves ran through government circles recently when an official report concluded what was already obvious to anyone who has seen how Japanese electronics firms have decimated the UK industry.

There is pitifully little left to Britain's consumer electronics empire. Although a specialist hi fi industry still flourishes, all mass-produced audio equipment is imported from the Far East. All the major tv production factories in Britain are now owned by foreign companies, mostly Japanese. Britain never has had a native video industry, and the few video recorders made here are assembled from kits of foreign parts.

The shining white hope was cellular radio. In June 1982 the UK Government announced that there would be two compatible but competing networks.

In December the Department ofTrade and Industry chose a consortium of British Telecom and Securicor, and a consortium of Racal and US company Millicom (whose share was later bought out by Racal). John Butcher, Parliamentary Under-Secretary of State for Industry, told Parliament that Racal had been chosen because the company estimated that 2000 people would be employed in cellphone manufacture in Britain by 1989, with a total of 6000 manufacturing jobs in Britain by 1989 when export potential was taken into account. BT-Securior, said Butcher, could be expected to produce a similar number of jobs – making a total of around 10000.

"Racal have given categorical assurances that the hardware of the system they would prefer to install will be manufactured in this country", said Butcher.

In February 1983 Kenneth Baker MP, then Minister for Information Technology, announced that the chosen technology was TACS (Total Access Communication System). This was derived from the AMPS (Advanced Mobile Phone System) developed by Bell Labs in the US. Baker told the House of Commons that the decision had been taken "with world markets in mind" and "could create up to 12000 new job opportunities in the UK by 1990".

The two rival services went on air in January 1985 and there are now around 350,000 subscribers, split 50/50 between the two systems. Cellnet estimates that the total UK market will be 1.5 million by 1991. Already Cellnet has bought 17 computer-controlled nerve centre "switches" and 400 base station transmitters all from Motorola in the US. Racal has bought five switches from Ericsson in Sweden and 355 transmitters, most from Ericsson but a few made under licence by Orbitel, a Racal-Plessey joint venture.

Only two firms manufacture cellphones in the UK, Excell and Cleartone. Racal's plans to manufacture at Seaton in Devon fizzled out. Motorola assembles some of its models in the UK. Japanese firms will soon start to assemble in the UK, but only under pressure from the EC.

Racal employs 450 people to run its Vodaphone network. Orbitel employs 250.

Although, as the DTI predicted, 10,000 jobs may have been created, most are in a service industry riding on foreign technology.

When I was preparing this piece I phoned Racal to check that my facts on the Vodaphone service were up to date. Racal's switchboard was out of action for the day. When I got through, the Racal press office admitted that I was one of many journalists who no longer received press releases because they had "changed computers, lost a lot of names and addresses in the process and had to rely on people phoning in to complain".

I then phoned Cellnet. It was mid-day Friday.

Sorry, said Cellnet's press and publicity office, there's no one who can help – they are all out on a rally. Try again Monday.

I left angry messages and finally got what I wanted from Cellnet's helpful boss, Colin Davis.

It wasn't until afterwards that I stopped to think.

Surely the whole point of cellular radio is that it lets people stay in touch even when they are out of the office?

The next white hope is CT2, the second generation cordless telephone which can be used like a budget cellphone. But a confusion of different standards looks likely to make the launch later this year a damp squib – or complete disaster. Either the launch will be cancelled, losing British manufacturers their lead over foreign competitors, or the public will be offered several incompatible systems which later have to be withdrawn from the market and replaced by units operating on a different standard.

"It's a pig's ear", admits one senior BT official. Next month I'll tell you why.

PE

BRAIN EMULATION

Through a newly established Neural Network Clearinghouse, Battelle is tracking a new compute technology that sets out to emulate the workings of the human brain.

The clearinghouse tracks the developments of researchers and companies working on neural network computers, machines that are being designed to function in a manner similar to neurons and their synapses.

In this new breed of computers, circuits are modeled after the brain's connections to allow them to recognize images someting conventional computers cannot do. Consequently, neural networks are expected to outperform conventional computers in tasks requiring processing of incomplete, unpredictable, and often inconsistent data such as speech processing, pattern recognition, and adaptive control.

Also, neural network computers will operate with lightning speed through the use of massive parallelism. This will give neural networks a high degree of fault tolerance the ability to recover gracefully from processor failure associative recall the ability to retrieve information instantaneously based on content and graceful degradation the ability to guess if there is no exact match for the requested information.

So far, neural network computers are still in an embryonic state, says Battelle's Dr. Klaus Obermeir. However, some experts predict they will claim half of the expected $600 billion robotics and computer market by the year 2000.

ED

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PIN-OUT PIN-UPS

Last month, in part one of the oscilloscope project I commented that the serious amateur electronics enthusiast should have two main items of equipment in the workshop, a meter and a scope. There are many more items that help to make designing, testing and repairing a simpler task, such things as power supplies, signal generators, amplifiers and the like. That's on the hardware side – what about the software side, the sources of information?

For all the sophistication of elegant test gear, none of it can be put to adequate use if you don't have data on the circuits and components of the designs being worked on. Taking a glance at the bookshelves beside me in my workshop as I write these words, I have text books, manuals and reference works that stretch for over 24 feet. That's before I even try to estimate the area covered in the loft by electronics magazines, some of them, PE in particular, dating back for decades. You never know when information, however basic, may suddenly become relevent to the task in hand. However much technology may change as new devices and techniques are introduced, the fundamental principles of many aspects of electronics will never change.

Access to technical data is of vital importance to anyone involved in electronics, whether an old hand at the game, or a raw beginner. Obviously, the cost of acquiring the data can restrict the amount of information stocked in your workroom, and in many instances the selective choice of condensed data will often prove adequate.

It is with this in mind that we present you with a data card this month. As you will have noticed, it consists of pin-outs for most of the cmos 4000 series of chips. Space prevented inclusion of every single ic, but those chosen show the pin functions for chips that are most likely to be used by most constructors. We deliberated for a while on whether to give you a selection of high speed cmos pin-outs instead, but concluded that the versatility of the 4000 series gives it greater appeal to a wider readership. No doubt sometime we shall offer you data on other chips, but cmos 4000 is so well entrenched in the realms of diy electronics that many published projects make use it in some form or other.

Ideally, of course, more advanced constructors should have the complete data on cmos chips, giving all their parameters from electrical characteristics and truth tables to test waveforms and applications notes. That, though, fills over 500 pages in my Motorola 4000 cmos manual, but in reality, knowledge and intelligent interpretation of the pin-outs will normally provide sufficient information for most constructors.

As a quick glossary of the more common meanings of pin abbreviations, Vdd and Vss are +ve and ground respectively, C = clock, D = data, E = enable, P = program, Q = output, R = reset, S = set, and a bar over a letter indicates inversion. Other meanings occasionally occur, but the chip function will normally clarify the pin's purpose.

I am sure you will find the data useful. **THE EDITOR**

PANNING MIXER

BY ROBERT PENFOLD

LET'S HAVE YOU OVER THERE... THERE... AND THERE

This versatile ten-input mixer design allows for a mix of mono and stereo line-level inputs with panning controls to build a realistic stereo sound field.

While there has been no shortage of mixer designs for the home constructor in the past, there seems to have been relatively few mixer projects specifically for the electronic music enthusiast. In particular, there appear to have been few previous designs that meet the requirements for operation in modern electronic music systems, where stereo outputs and multiple outputs are quite common. You no longer need to have a large number of instruments in order to need a sizeable mixer. With just a couple of synthesisers you could have eight mono signals and a stereo signal to mix down into a stereo output. Suitable ready-made mixers are available, and are extremely good, but generally have prices of some hundreds of pounds. In fact it would be easy to set up a system where the mixer cost more than the instruments with which it was being used.

This design has two stereo inputs and eight mono inputs. It has been designed with flexibility in mind, and it can easily be wired for any combination of stereo/mono inputs that totals ten inputs (eg, four stereo and six mono inputs). For each stereo input, volume, balance and mute controls are provided. The controls for the mono inputs are much the same, but the balance control is replaced with a pan type. In other words, each mono input can be placed anywhere in the stereo sound stage, from the extreme left to the extreme right. There is also a master volume control. Tone controls have not been included as the overall tone can usually be adjusted on the amplifier, and the tone of individual instruments can be adjusted via their filter controls. The unit is powered from an internal mains power supply. It is housed in an inexpensive 19-inch rack-mount case which enables it to easily fit into a modern electronic music system based on rack-mount sound modules.

A low noise level is obtained by using high quality ultra-low noise operational amplifiers in the mixer stages. However, if noise performance is not a major consideration the circuit will perform reasonably well using lower cost types. The unit is only intended for use with instruments such as synthesisers and samplers which provide an output level

of a few hundred millivolts rms, but it should also work properly with high output guitar pick-ups. For operation with low output guitar pick-ups or microphones a suitable preamplifier would be needed. There is plenty of space available inside the unit for preamplifiers, and the power supply has plenty of excess capacity for add-on circuits.

MIXING IT

The most fundamental form of mixer is a passive circuit, as shown in Fig.1. The circuit after the "fader" potentiometers must provide two functions, one of which is to minimise any interaction between the two controls. Ideally, adjustment of one control should have no effect on the other channel at all. The second function is to isolate the inputs from one another, so that the signal at one input does not significantly drive the

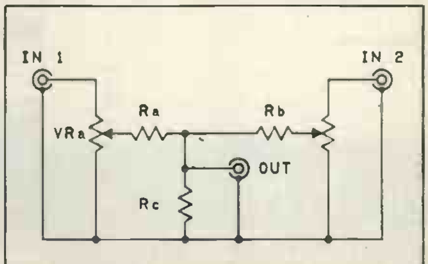


Fig.1 *The basic passive mixer circuit.*

outputs connected to other inputs. Ideally, there should be total isolation between inputs, but in practice a relatively poor degree of isolation is unlikely to cause any real difficulties.

In this basic passive mixer circuit the series resistors at the outputs of the potentiometers help to minimise any interaction between the two controls and to give some degree of isolation between the two inputs. The resistor across the output further reduces the interaction/isolation problem. The higher the value of the series resistors, and the lower the value of the output resistor, the better the performance of the mixer. However, the better the mixer performs, the greater the losses through the circuit. If these losses are very high, a high gain amplifier will be needed at the output in order to compensate for them, and this would compromise the noise performance of the circuit.

OPAMP SOLUTION

An opamp provides an ideal solution to the problem in the form of the inverting mode amplifier, Fig.2a. The very high voltage gain of an opamp, plus a negative feedback action, results in the voltage at the inverting input being held at the same voltage as the non-inverting input. This is the earth potential, and what is termed a "virtual earth" is formed at the inverting input.

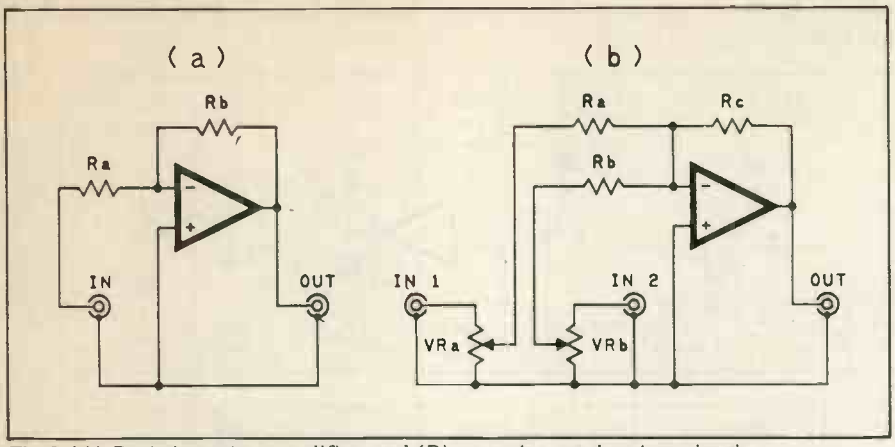


Fig.2 *(A) Basic inverting amplifier, and (B) summing mode mixer circuit.*

The way in which the feedback action functions is very simple. Due to its high gain, only a very small voltage difference across the inputs of the opamp is sufficient to send the output fully positive or negative. It goes negative if the inverting (–) input is at the higher potential, or positive of the non-inverting (+) input is at the higher voltage. If the input is left open circuit, the amplifier stabilises with the output and the inverting input held at earth potential. If the signal should drift higher in voltage, the coupling through Rb results in the inverting input going more positive as well, which sends the output lower in voltage again. Any drift lower in voltage takes the inverting input to a reduced potential, and sends the output higher in voltage.

An input voltage applied to the circuit will result in the two input voltages of the opamp becoming unbalanced, and the negative feedback action will again counteract this and restore the balance of the input voltages.

As a simple example, assume that the input is taken one volt positive, and that Ra has the same value as Rb. This signal takes the inverting input positive, and causes the output to go negative. The output will go negative by one volt, as a simple potential divider action then gives zero volts at the inverting input. In fact any input voltage will cause an equal but opposite output voltage to be generated. The circuit acts as a simple unity gain inverting buffer stage. Suppose that Rb is made ten times higher in value than Ra. The circuit functions in much the same way as before, but in order to balance the input voltages much larger output voltages must be produced. In fact ten times the output voltage will be needed in order to balance the input voltages by a potential divider action. The mathematics of the inverting mode circuit are beautifully simple. The voltage gain is equal to Rb divided by Ra. The input impedance is equal to the value of Ra (by virtue of the fact is connected between the input and a "virtual earth").

To get an opamp inverting mode circuit to act as a mixer it is merely necessary to add extra input resistors, as in the basic twin input mixer circuit of Fig.2b.

SUMMING UP

This is known as a "summing mode" circuit, because the circuit responds to the sum of the input voltages. This is again a matter of a simple potential divider action, with the output voltage assuming a level that will balance the combined input voltages. The input impedances are equal to the values of Ra and Rb, and the voltage gains are controlled by the ratios of Ra to Rc and Rb to Rc (and they do not have to be the same). Operational amplifiers were originally designed for this sort of mathematical operation on dc signals for applications in analogue computing. They work just as well at the relatively low frequencies involved in audio applications, though.

What makes the summing mode configuration so attractive for audio mixing is that the virtual earth at the inverting input provides what (in theory anyway) is total isolation between the two inputs. One "fader" control has absolutely no effect on the other, and a signal fed to one input is totally blocked from the other input. In practice an opamp will not have theoretically perfect performance, and in particular it will not have infinite voltage gain. However, provided the device used is one which has good audio frequency performance, any interaction between faders and feedthrough from one input to another will be negligible.

In theory, you can have as many inputs as you like. It is just a matter of having an input resistor and "fader" potentiometer for each input you require. In practice, things are far less clear cut. Any mixer circuit being published is usually followed by a few readers' letters asking for information about the maximum number of inputs that can be used with the circuit. *(Thanks Robert for anticipating Ed's writer's cramp syndrome! Ed).* This is very much a "how long is a piece of string?" type question. The theory ignores the fact that a certain amount of noise is likely to be picked up in the input wiring. Even if this pick-up can be kept down to an acceptable level, there is still the noise of the opamp to be considered.

An often overlooked fact is that the noise output of the device is related to the number of inputs used. Each time an input resistor is added, it effectively shunts any existing input resistor or resistors. In other words, as far as noise performance is concerned, ten 100k input resistors have a combined resistance of 10k and are the same as using one input with a resistance of 10k. The mixer circuit featured here has a voltage gain of about three times, but with ten inputs it has the noise of an amplifier having a gain of thirty. Using ultra low noise opamps and carefully laid-out wiring it should be possible to have twenty to thirty inputs and still obtain satisfactory performance. There is no "hard and fast" upper limit though, and it depends on the amount of noise you are prepared to accept.

PANNING

A slight complication with a mixer of this type is that some of the input signals are mono, but the output is stereo. There must be some means of mixing these signals into both channels and panning them to the desired position in the stereo sound field. Remember that mixing a mono signal equally into both channels places it at the middle of the sound stage, while mixing it more strongly into one channel than the other offsets it towards the side of the stereo sound field where it is stronger. The greater the imbalance, the greater the apparent offset.

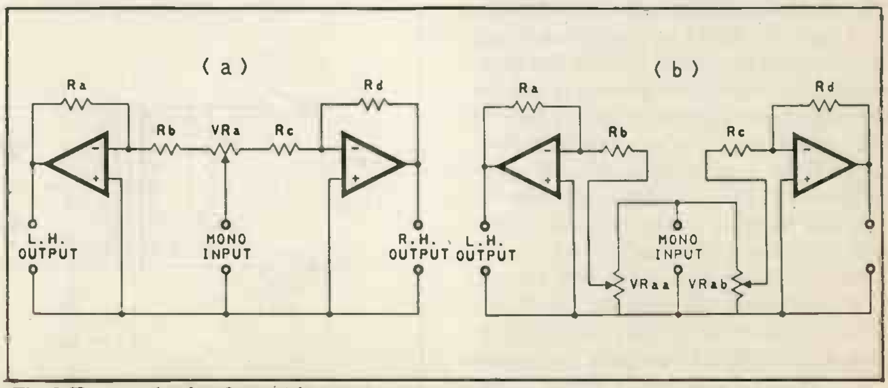


Fig.3 *Two methods of providing panning.*
(A) is more simple and involves having a variable input resistance.
(B) is the one chosen for this project, and uses a dual-gang potentiometer.

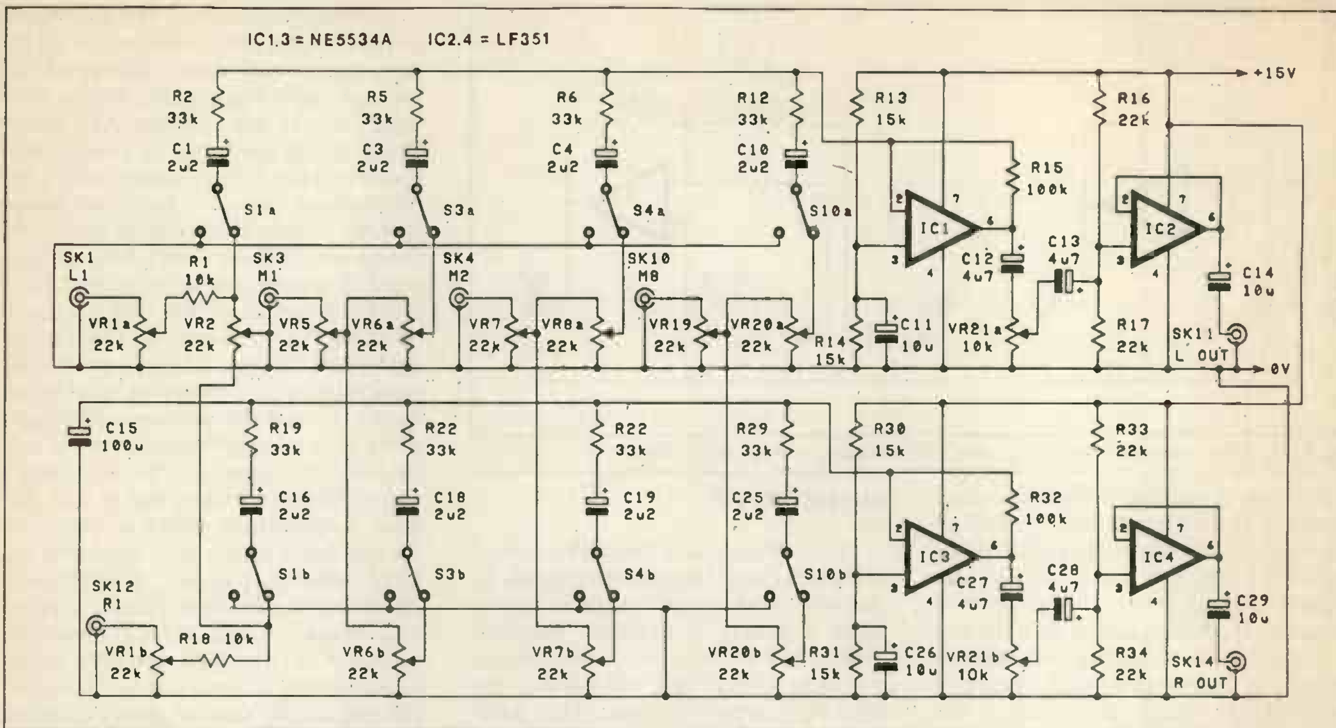


Fig.4 *The main mixer circuit diagram.*

Although the sound stage that is produced by this type of mixing is totally artificial, it gives what is usually a very realistic and vivid stereo effect. In fact the most realistic stereo effects I have heard are ones produced in this way!

Two methods of providing the panning are shown in Fig.3. The method shown in (a) is the more simple, and it involves having a variable input resistance. With VRa at a central position the input resistances of the two mixers are identical, and they have exactly the same voltage gain. The mono input signal therefore appears at the two stereo outputs at equal amplitude, placing it at the centre of the sound stage. Moving VRa off centre makes one input resistance higher in value, while the other is made lower in value. This gives reduced gain in one channel and increased gain in the other stereo channel, moving the signal to one side of the stereo field. Adjusting VRa off-centre in the opposite direction again gives an imbalance in the voltage gains of the two channels, and pans the signal to the other side of the stereo sound field.

A slight drawback of this system is that it cannot set the signal level in one channel at zero, and consequently it can not pan the signal right over to one side of the sound stage. In practice a modest amount of separation is actually quite sufficient to place a signal right over to one side or other of the stereo field, and this circuit can give very good results. However, the system of Fig.3b is the one that was finally adopted for this mixer design. This is marginally more expensive as it requires a dual gang pan potentiometer, but it allows a signal to be genuinely panned right over to either side of the sound stage.

It is really just twin volume control style variable attenuators, very much like the "faders" used at the input of the circuit. There is an important difference in that the two sections of the pan control must be connected in anti-phase. Thus, with the control at a central setting, both channels are attenuated by about 6dB, and the signal is placed at the centre of the sound field. Moving the control off-centre reduces the attenuation in one channel but increases the attenuation in the other channel. This gives the desired effect, with the signal being panned over to one side. With the pan control set fully one way or the other the attenuation in one channel is reduced to zero while in the other it becomes infinite. Provided the pan potentiometer is a linear type, adjusting it will only affect the position of the signal in the stereo field, and it will not have any significant effect on the overall level of the signal.

MIXER CIRCUIT

The main circuit diagram for the mixer is provided in Fig.4, but the mains power supply circuit is shown separately in Fig.5. Note that in Fig.4 only one stereo input and three mono inputs are shown, but the two stereo input stages are identical, as are the eight mono stages.

The circuit is very much along the lines described previously. The stereo inputs have the fader potentiometers followed by the standard form of balance control, and the mono inputs use the configuration of Fig.3b. The mixers stages are summing mode types based on IC1 and IC3. In the original circuit I used LF351s for IC1 and IC3, but the noise performance was disappointing. I therefore replaced them with the more expensive NE5534As, and these would seem to justify the extra expensive. They seem to give a reduction in the noise level of around 30dB (ie, a decrease by a factor of about ten). Of course, in some applications a really low noise level might not be needed. This is something that depends on the signal levels the unit will have to handle, and on how much noise there happens to be on the input signals.

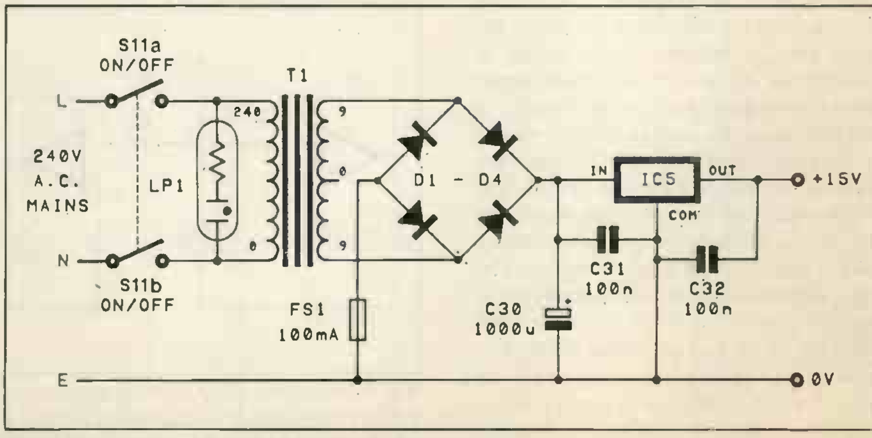


Fig.5 *The mains power supply circuit diagram.*

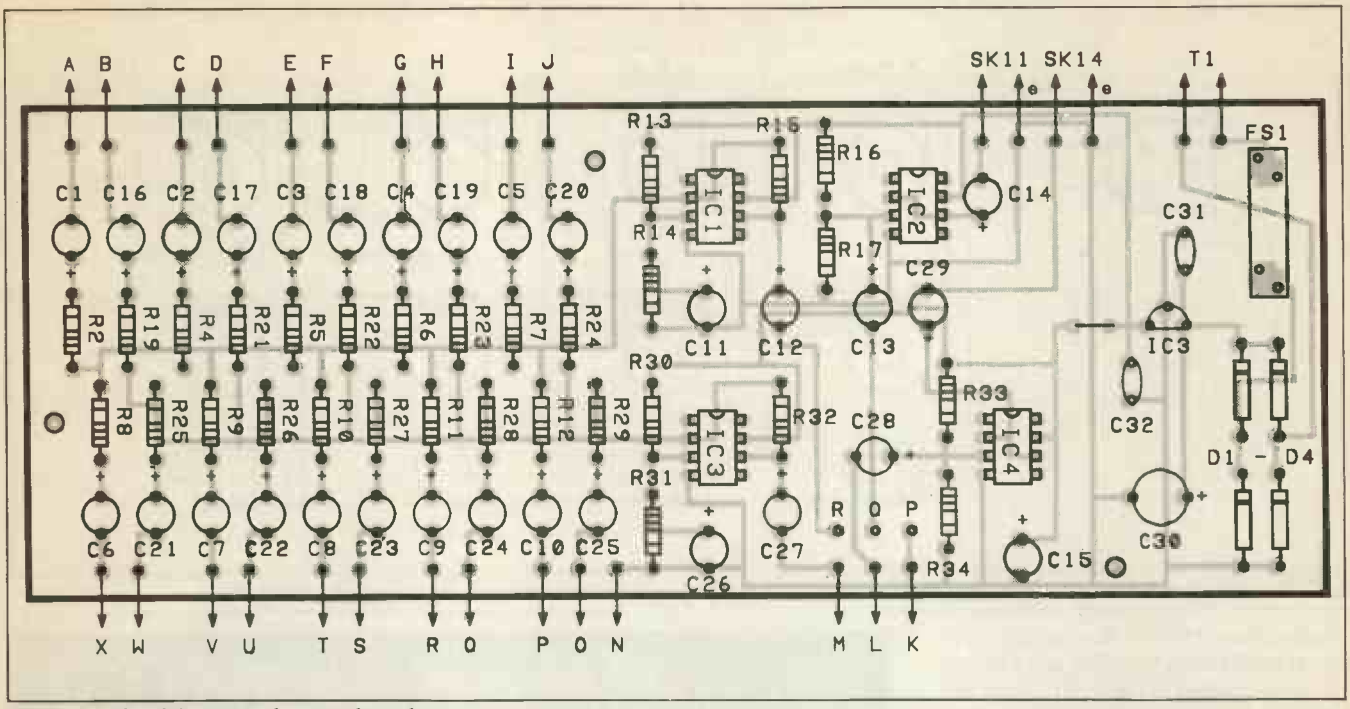


Fig.6 *Details of the printed circuit board.*

With most modern instruments it is certainly worthwhile using the NE5534s though. The voltage gain of each mixer stage is about 10dB (a little over three times), but losses through the input circuits mean that the overall voltage gain of the circuit (with the gain controls set at maximum) is not much more than unit.

There is a mute switch at each input, and these are useful for cutting out any inputs that are not required. Apart from cutting off any hum or noise from an instrument that is not actually in use, it is also a convenient way of temporarily silencing an instrument (or instruments) when you are sequencing, and wish to concentrate only on certain tracks. With the suggested method of connection any unused inputs are short circuited to earth. This ensures that there is no slight breakthrough of any muted inputs, and that there is no significant stray pick up of mains hum at muted inputs. It also means that switching off unused inputs does not reduce the background "hiss" level at all, but the noise should be insignificant anyway if ultra low noise devices are used for IC1 and IC3.

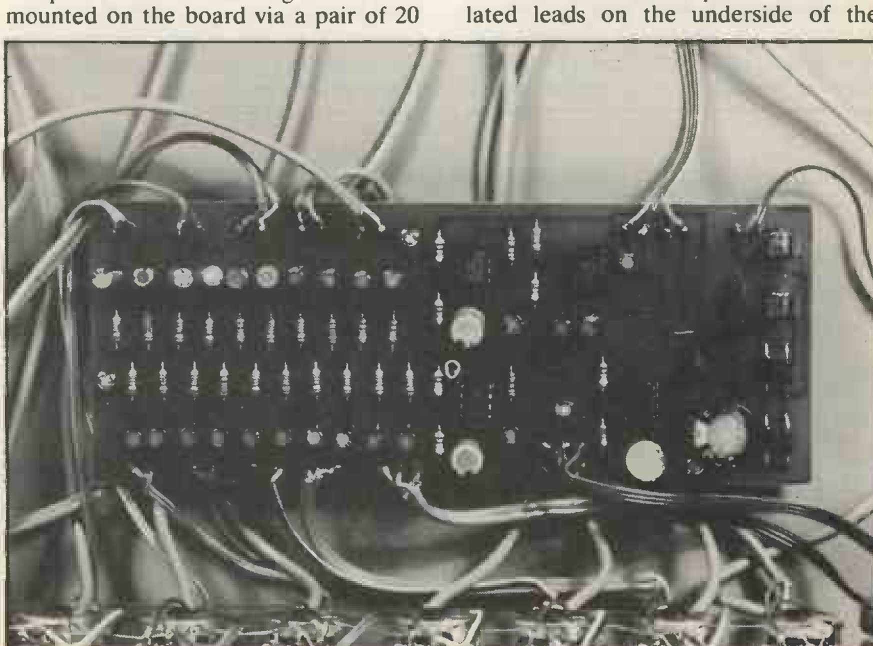
Each mixer stage is followed by the master gain control potentiometer and a unit voltage gain output stage which gives a low output impedance. The noise performance of the operational amplifiers used in the buffer stages is far less critical than that of those used in the mixer stages. Consequently, devices such as the TL081, LF351, and uA741C are perfectly suitable for use in these stages.

The mains power supply has full-wave bridge rectification followed by a large smoothing capacitor (C30) and a 15 volt monolithic voltage regulator. This gives a very well smoothed output, which is important in the interest of obtaining a low noise level from the mixer. T1 can be very small 9 – 0 – 9 volt mains transformer having a secondary current rating of about 75 to 100 milliamps. The current consumption of the mixer circuit is only about 10 milliamps or so. Fuse FS1 should be an anti-surge type and not the more usual "quick-blow" variety (which would tend to "blow" at switch-on as C30 charged up).

CONSTRUCTION

Refer to Fig.6 for details of the printed circuit board. Building the board is about the most simple aspect of construction. It is largely straightforward, but a few points are worth noting. The fuse is mounted on the board via a pair of 20 millimetre fuse-clips. Use plenty of solder when fitting these, so that they are provided with a physically strong mounting. The integrated circuits are not mos types and do not require any special handling precautions. The NE5534A is not a very cheap device though, and I would strongly recommend the use of holders for IC1 and IC3. Do not overlook the single link wire (just to one side of IC5). At this stage only pins are fitted to the board at the points where the connections to off-board components will eventually be made.

An unexpected problem with the prototype was a slight background hum which seemed to be due to a hum loop. To pre-empt this possible problem it is advisable to add a couple of stout insulated leads on the underside of the



Photograph of the pcb in position.

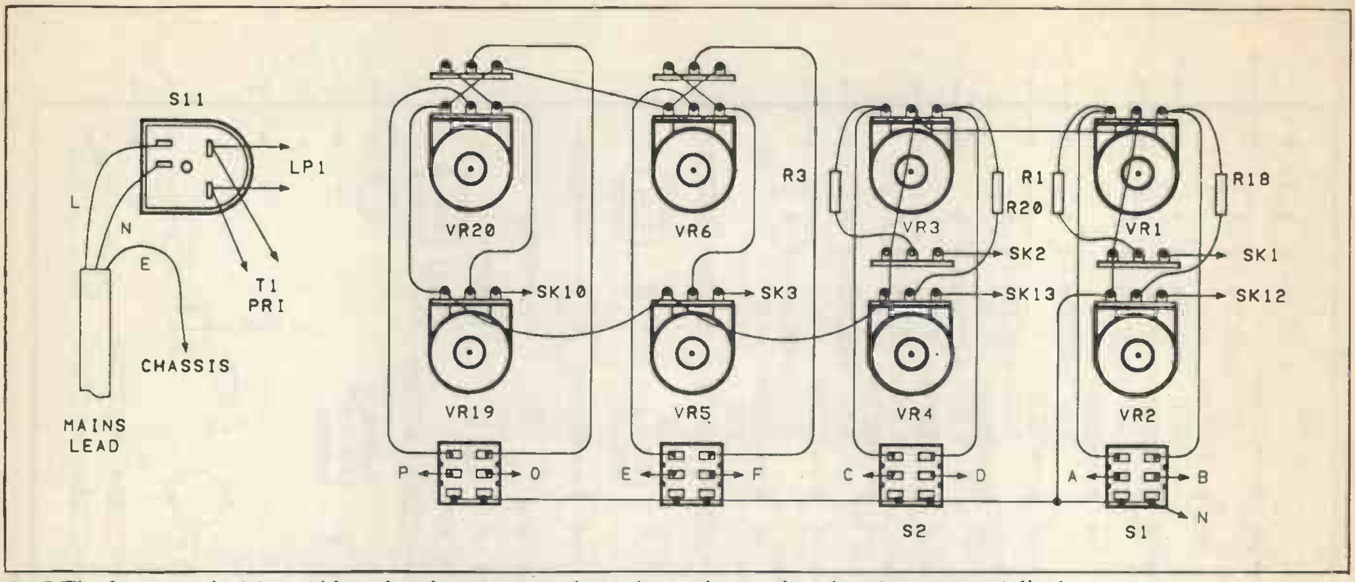
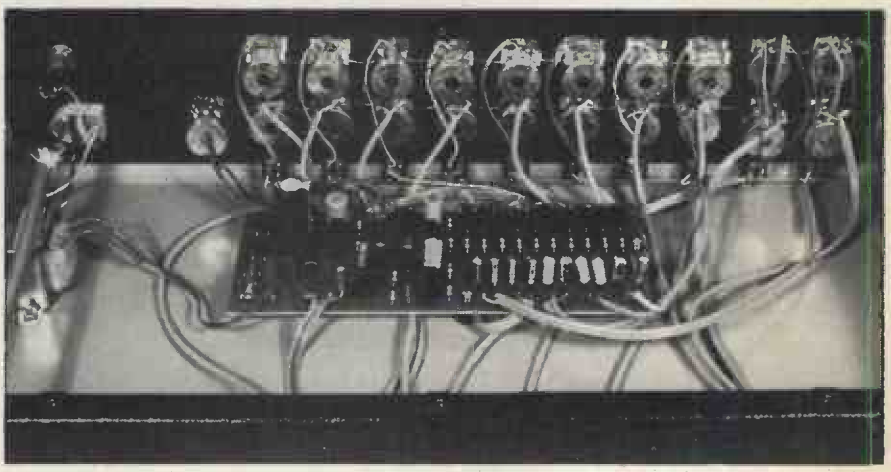


Fig.7 *The front panel wiring. Although only two mono channels are shown, the other six are essentially the same.*

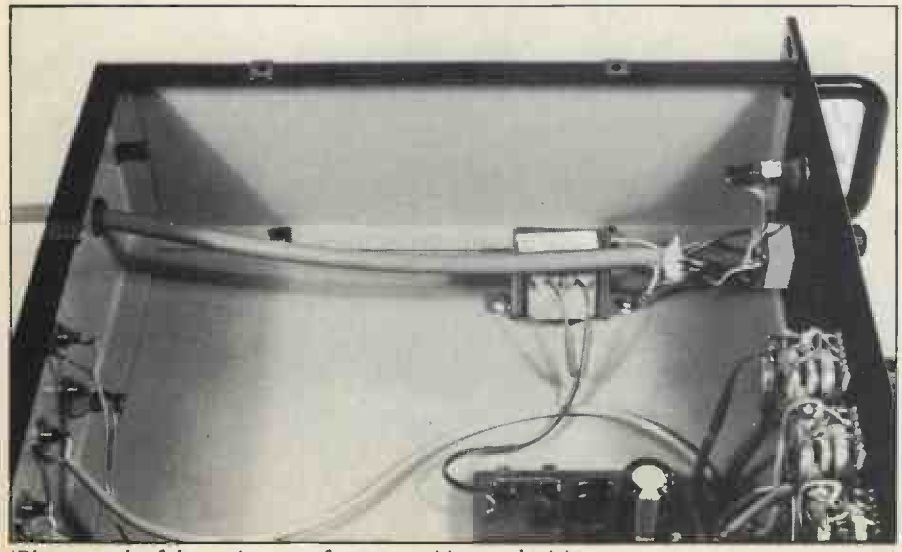
board. Connect the earth track at or near the take-off points for SK11 and SK14 to the earth track near pin 4 of IC3 and pin 4 of IC4. On the prototype this seemed to totally silence the slight background buzz. If you are not going to use NE5534As for IC1 and IC3 these leads are not really necessary, as the background hiss level will almost certainly be much stronger than any hum.



Photograph of panel and pcb connections layout.

ON THE RACK

I needed the unit to fit in with some 19 inch rack-mount instruments, and a 2U size rack-mount case was the obvious choice as the housing for the unit. I used an inexpensive type that is only recommended for light-duty applications, but which seems to be more than adequate for this design. If you use a different case you should choose carefully. It would be very easy to buy a rack-mount case that cost two or three times as much as all the other components in the unit. The circuit board does not merit a case as large as a rack-mount unit, but remember that there are some thirty two controls and a neon indicator to accommodate on the front panel. This necessitates a case with a pretty large front panel. If you require slider type fader controls an even greater front panel area will be needed. In fact a console style case specifically intended for mixer applications or a custom made case would be needed.



Photograph of the mains transformer position and wiring.

I covered the front panel with a brushed aluminium effect veneer to make the unit more photogenic, but the specified case has a mat black panel which matches many electronic instruments quite well. It is a good idea to add legends to the front panel. This is not just a matter of making the unit look pretty – it will be very much easier to use if the controls are clearly labelled.

CONTROL LOGIC

Sensible placing of the controls is mandatory if the unit is to be usable. The logical placement is with the three controls for each input mounted in a vertical row. Try to have the on/off switch and mains indicator mounted a reasonable distance away from the other controls. This makes it much easier to avoid problems with stray pick up of mains hum. The fourteen input sockets are mounted on the rear panel, and the input sockets should be positioned opposite their front panel controls. Apart from making it easier to get equipment plugged into the right sockets, this also makes wiring up the unit very much easier. I used phono sockets, but with many setups 6.35 millimetre jacks or a mixture of these and phono sockets might be the most convenient.

The printed circuit board is mounted on the base panel of the case, close to the fader controls. This keeps the input wiring short, which again eases problems with pick up of mains "hum". The usual stand-offs or spacers are needed to hold the connections on the underside of the board well clear of the metal casing. T1 is mounted on the base panel, close to S11 and LP1. A soldertag is fitted on one of its mounting bolts to provide a chassis connection point for the mains earth lead. For safety reasons the case must be properly earthed.

COMPONENTS

RESISTORS

R1,3,18,20	10k (4 off)
R2,R4 to R12, R19, R21 to R29	33k (20 off)
R13,14,30,31	15k (4 off)
R16,17,33,34	22k (4 off)
R15,32	100k (2 off)

All ¼ watt 5% carbon film

POTENTIOMETERS

VR1,3	22k log dual gang
VR2,4	22k lin
VR5,7,9,11,13, 15,17,19	22k log
VR6,8,10,12, 14,16,18,20	22k log dual gang
VR21	10k log dual gang

CAPACITORS

C1 to C10, C16 to C25	2μ2 63V radial elect (20 off)
C11,26	220μ 16V radial elect (2 off)
C12,13,27,28	4μ7 63V radial elect (4 off)
C14,29	10μ 25V radial elect (2 off)
C15	100μ 25V radial elect
C16	1000μ 35V radial elect
C17,18	100n ceramic (2 off)

SEMICONDUCTORS

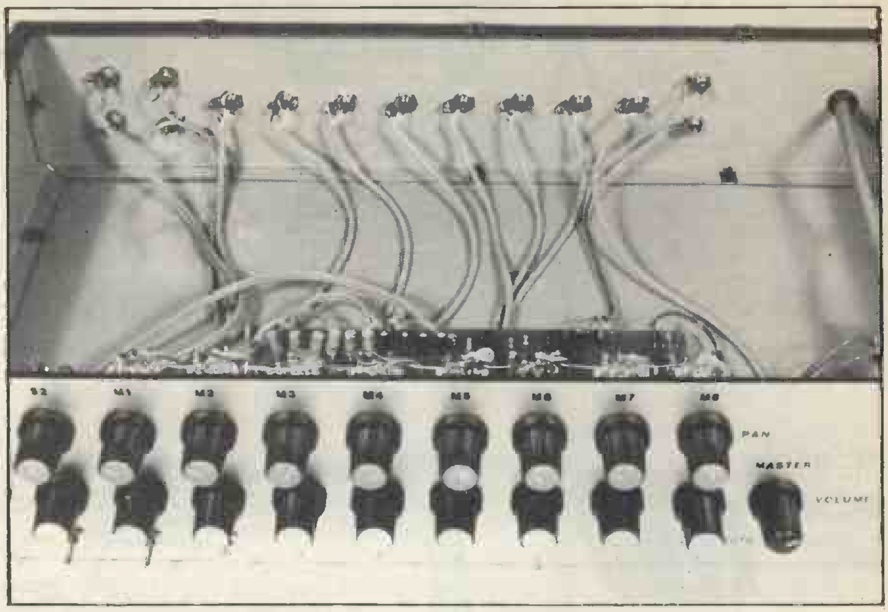
IC1,3	NE5534A (2 off)
IC1,4	LF351 (2 off)
IC5	μA78L15
D1,2,3,4	1N4002 (4 off)

MISCELLANEOUS

SK1 to SK14	Phono socket (14 off)
T1	9-0-9V 100mA sec., mains primary
FS1	100mA 20mm anti-surge
S1 to S10	DPDT sub-min toggle (10 off)
S11	Rotary mains

Mains panel neon, Printed circuit board, 2U rack-mount case, 22 control knobs, mains lead and plug, 8 pin dil holder (4 off), wire, screened lead, pins, etc.

The 2U rack-mount case is available from Rackx Products, PO BOX No. 1402, Mangotsfield, Bristol, BS17 3RY.



Photograph showing connections to rear-mounted sockets.

WIRING

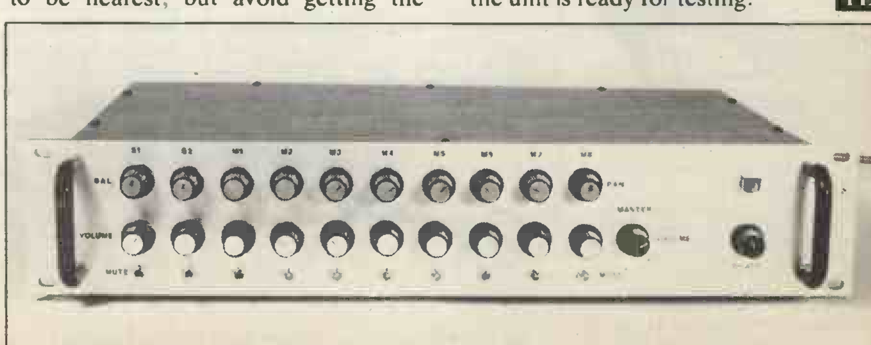
The wiring is detailed in Fig.7, but the connections for only a few channels are shown. The wiring for each mono channel is essentially the same as the wiring for every other mono channel, and Fig.6 provides all the information you need. This amount of wiring is inevitably going to take quite a long time, but do not be tempted to rush things. Take things in a sensible order. I found it was easiest to put all the earth wiring in first, using 22 swg tinned copper wire and taking care to avoid any short circuits to this wiring. Then the other leads and the two resistors per stereo channel can be added, using insulated connecting wire and pvc sleeving over the leadout wires of the resistors. This can all be done with the front panel removed from the case.

With the front panel refitted, the wiring from the controls to the board and sockets can be added. Where this wiring is reasonably short (say about 100 millimetres or less) it does not need to be screened, but the longer leads (particularly the ones which connect to the input sockets) must be screened. It is worth noting that the printed circuit board has ten identical pairs of inputs, and it does not matter which pair is fed from which set of front panel controls. You can simply use whichever pair of inputs happen to be nearest, but avoid getting the stereo channels swapped. This would result in some pan/balance controls operating with the opposite sense to some of the others.

SPLITTING IMAGE

If you require a different mix of mono and stereo inputs, this is easily obtained by using the right sets of potentiometers, resistors, and sockets for the split you require, and then wiring them up in the appropriate manner. Remember that the pairs of inputs on the board are all the same – it is the front panel components and their wiring that determine whether an input is a mono or stereo type. If your requirements may vary from time to time, it is better to have lots of stereo inputs. Driving both inputs from a mono source will give good results, with the balance control acting as a pan control.

To complete the unit the connections from VR21 to the board are added, the output sockets are wired to the board, and the small amount of power supply wiring is completed. There is no connection to the "0V" secondary winding of T1, and this lead should be trimmed short. Some of T1's leads may be too short to reach the tags to which they must be connected. Insulated extension leads must then be used, but use pvc sleeving to cover over the soldered joints. After a final check of the wiring the unit is ready for testing. PE



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Our approved parts set consists of case, PCB, all components (including high permeability toroidal cores, ICs, transistors, class X and Y suppression capacitors, VDRs, etc.) and full instructions.

PARTS SET **£28.50** + VAT

Some parts are available separately. Please send SAE for lists, or SAE + £1 for lists, circuit, construction details and further information (free with parts set).

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The Knight Raider can be fitted to any car (it makes an excellent fog light!) or with low powered bulbs it can turn any child's pedal car or bicycle into a spectacular TV-age toy!

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DECEMBER 1987

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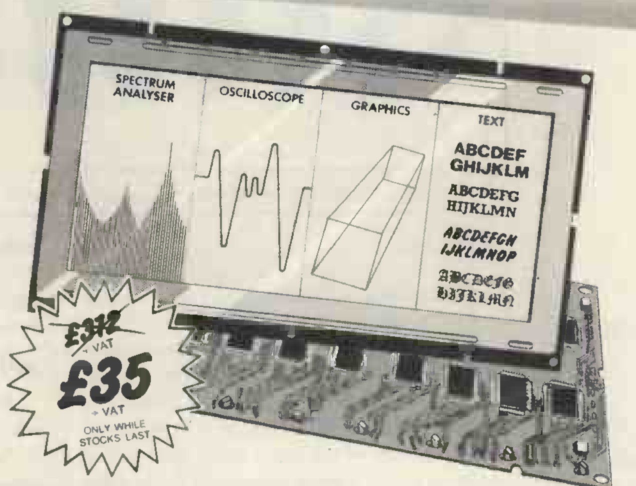

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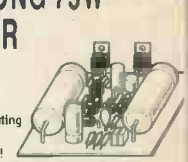
FEATURED IN PE
JULY 1988



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You can read all about it in the July issue of PE, but why bother with words when your ears will tell you so much more?

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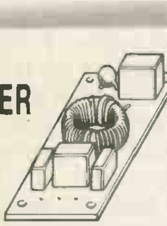

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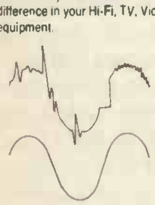

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BIO-FEEDBACK

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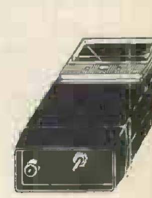

Bio-feedback comes of age with this highly responsive, self-balancing skin response monitor! The powerful circuit has found application in clinical situations as well as on the bio-feedback scene. It will open your eyes to what GSR techniques are really all about.

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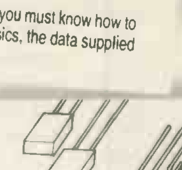
LEDs



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Parts set available separately. We also have a range of accessories, professional electrodes, books, etc. Please send SAE for lists, or SAE + £2 for lists, construction details and further information (free with parts set).

SEMICONDUCTORS

BY ANDREW ARMSTRONG

PART 12 – TTL AND ECL

Bipolar logic families are not so widely applicable to the enthusiast as to the professional. They can, however, offer advantages where speed is essential.

Last month we covered cmos logic. This month we shall look at two bipolar logic families, ttl and ecl. Though both bipolar, these logic families are very different in their operation. TTL is a saturated logic, which means that when its outputs switch one way or the other one transistor or another is switched hard on, and is in saturation. The advantage of this is that the logic level is well defined, but the disadvantage is that there is a significant delay on switching due to charge stored in the base of the output transistor. ECL is a non-saturated logic system, in which 0 and 1 are voltages approximately one volt apart. At either voltage the output stage of the ecl gate is conducting, and is working, effectively, in a linear mode.

First this month, a few words about ttl. TTL is not dead yet, and may not die in the foreseeable future. It hangs on tenaciously for at least three good reasons. First of all, it is cheap because it has been in volume production for a long time. Secondly, it is sturdy and easy to use. The third reason is that, if ttl-like performance in terms of speed etc is required, this can only be provided by ttl itself, or by 74HC or HCT series cmos. The range of HC and HCT cmos does not cover the full range of what is available in ttl, so some designs may require certain ttl gates. It is for this reason that 74HCT is produced, 74HCT and 74LS chips may be mixed freely within a circuit. The main difference is that the 74HCT consumes a lot less power, and costs more.

From the point of view of the amateur constructor, the important characteristic of ttl are that it is cheap and easily obtainable. It has the disadvantage of being unsuitable for most battery powered projects, because it is so power-hungry.

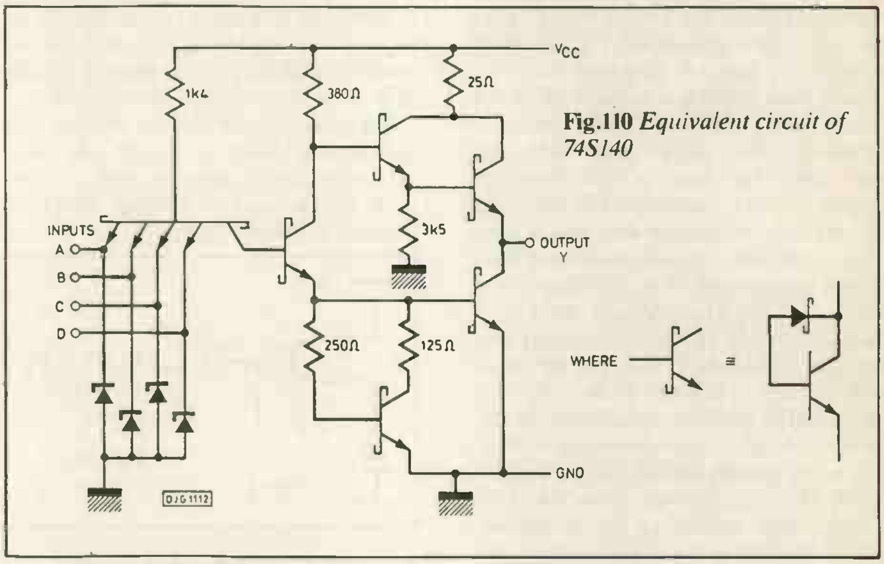


Fig.110 *Equivalent circuit of 74S140*

TTL TYPES

Originally there was just standard ttl. There are now a number of different families, of which probably the most useful is low power Schottky. Table 8 shows the characteristics of a number of the different families. As you can see, low power Schottky is much faster than low power, but only consumes double the power, while standard ttl consumes ten times the power of low power Schottky. Both standard and low power Schottky chips are available from component suppliers, but constructors are strongly advised to stick to LS gates.

As the table shows, LS logic has the lowest speed-power product. This is a measure of how much energy is required for a logic switching operation. Clearly the smaller the amount of energy, the better. Taking it to extremes, if you had to turn on and off the entire National Grid as a logic switching operation, then no plausible amount of power would provide substantial computing capacity, while if only one electron had to be moved per logic operation, then powerful computers could be run from little solar cells like they use in a calculator.

TABLE 8

SERIES	GATES		FLIP FLOPS	
	Speed/ power product time	Propagation delay	Power dissipation	Clock input frequency range
54/74	100pJ	10ns	10mW	dc to 35MHz
54LS/74LS	19pJ	9.5ns	2mW	dc to 45MHz
54L/74L	33pJ	33ns	1mW	dc to 3MHz
54S/74S	57pJ	3ns	19mW	dc to 125MHz
54H/47H	132pJ	6ns	22mW	dc to 50MHz
54/AS	18pJ	1.8ns	10mW	–
54/74ALS	4pj	4ns	1mW	dc to 50MHz
54/74F	6pj	2ns	3mW	dc to 100MHz
54/74FACT	–	1ns	$1\pi W$	dc to 125MHz

Note: The FACT family is ttl compatible cmos, and is shown for comparison purposes only.

Generally speaking, the fanout capability of LS gates driving LS gates is the same as that of standard gates driving standard gates. LS gates driving standard gates, on the other hand, normally have a fanout of two. For this reason, it is usually advisable to mix families. The limitation on fanout occurs because, in order to switch ttl inputs it is necessary to sink or source current to them while maintaining a certain logic level. The outputs of ttl gates have a limited sink or source capability, while maintaining the specified logic 0 or logic 1 voltages.

Having said earlier that ttl is saturated logic, it is interesting to note that Schottky and low power Schottky are not quite saturated. It is because they are not saturated that they switch much faster per unit power consumed. Fig.110 shows how this is done. A saturated transistor would have much less voltage on its collector than on its base. In this circuit, a Schottky diode bleeds away drive current from the base as the transistor begins to enter saturation. The following figures help to explain why this is so: a typical transistor in saturation may have a base voltage of 0.7V and a collector voltage of 0.1V. The forward drop of a Schottky diode at modest currents may be only around 0.1V, so in Fig.110, what will happen in practice is that the base drive will be cut back to maintain the collector voltage at approximately 0.5V. (I know this doesn't add up, but a transistor not in saturation will need less base drive voltage than one driven into saturation. The base voltage required to hold the transistor not quite in saturation is likely to be nearer to 0.6 volts than to 0.7 volts.)

In the circuit diagram shown, that of a 74S140, individual Schottky diodes are not shown. Because this circuit is all on one chip, it is possible to improve on the situation in which discrete components are used. The Schottky diode is included in the collector diffusion of the Schottky transistors in this type of ic.

OPERATIONAL REQUIREMENTS

Overloading a logic output may prevent it from delivering the specified 0 and 1 levels, though some samples of gates will tolerate a moderate overload. Equally, some gate inputs will sulk the moment that the logic levels fall out of specification, while many will continue to work with slightly out of spec voltages. For this reason, it is always advisable to calculate the loading on any gate input which is called upon to do much driving, rather than to assume that if the prototype works, then all units will work. It is not unknown for projects to fall foul of this problem, and a minority of readers simply cannot get them to work.

74-series ttl requires a power supply of 5V ±5%. 54-series (military specification) is rated to work over a power supply variation of ±10%. The power supply should be decoupled at regular intervals on the pcb layout, so that there is never a long length of power supply track with a number of gates connected to it, without at least one decoupling capacitor in the vicinity. TTL switches very fast and draws very sharp spikes of current from the power supply. It is much better for this current to circulate round a short length of track and be supplied by a decoupling capacity rather than to ring around the power supply track to the entire pcb.

Because ttl works faster than cmos, and because it runs on lower supply voltages than 4000-series cmos, it tends to be susceptible to electrical interference. To minimise this effect, tracks should be kept moderately short, and clock signals should not be taken from board to board with great big long wire connections.

There remains little more that I would wish to say about ttl, except that clock generator circuits used in cmos are not used in ttl, and a suitable ttl clock generator is shown in Fig.111.

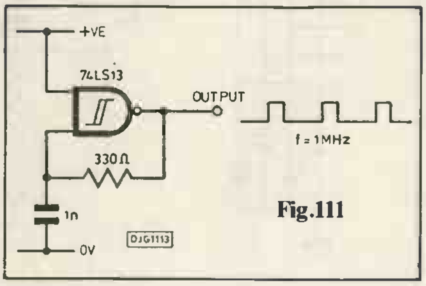


Fig.111

EMITTER COUPLED LOGIC

Emitter coupled logic is only of limited use to the home constructor. The most likely area of application for ecl would be in high speed dividers for frequency counters. As such, ecl is more likely to interest the radio amateur who is operating on vhf than the general electronics enthusiast. However, I think that a little bit of knowledge of ecl is of interest for its own sake.

Many people consider that designing with ecl is a bit of a black art, but it is not at all difficult once your have learned a few simple rules. The first important point to grasp is that the outputs of emitter coupled logic source current but connect sink it, because ecl chips are not provided with internal pull-down resistors. In order to make ecl gates work, suitable value pull-down resistors must be connected between gate outputs and the negative power supply.

This brings me to another point about ecl. Conventionally, ecl is powered from 0V and –5.2V, rather than as with ttl, from 0 and +5. This would seem to be an academic difference, but the logic levels in ecl are defined relative to the 0V rail, which is the positive supply, and if there is power supply variation, then the logic switching levels will remain more constant relative to the 0V then to the –5V supply. This aspect of ecl does give rise to some problems when converting logic signals between ecl and ttl or cmos, but special interface chips powered from ±5 are available. These are generally used to convert from ecl to ttl. Conversion in the other direction is often carried out by means of a resistor network, as shown in Fig.112.

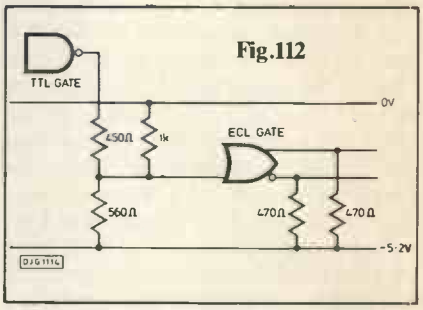


Fig.112

One useful aspect of ecl is the open emitter drive which can be used very much like open collector ttl. With open collector ttl, if any output is at logic 0 then all outputs joined to any single point are effectively at logic 0, while, with ecl, it is the other way round. If any output is at logic 1, of a series of outputs joined to the same point, then the total output is at logic 1. This is effectively the logic OR function, and this effect of ecl is called wired OR capability. Careful thought and the use of Boolean algebra can make use of this facility to minimise the number of logic gates required in any given application. The speed penalty for each wired OR connection is approximately 100ps.

To illustrate all this, the circuit of an ecl OR/NOR gate is shown in Fig.113. This is the basic form of ecl gate, such as the

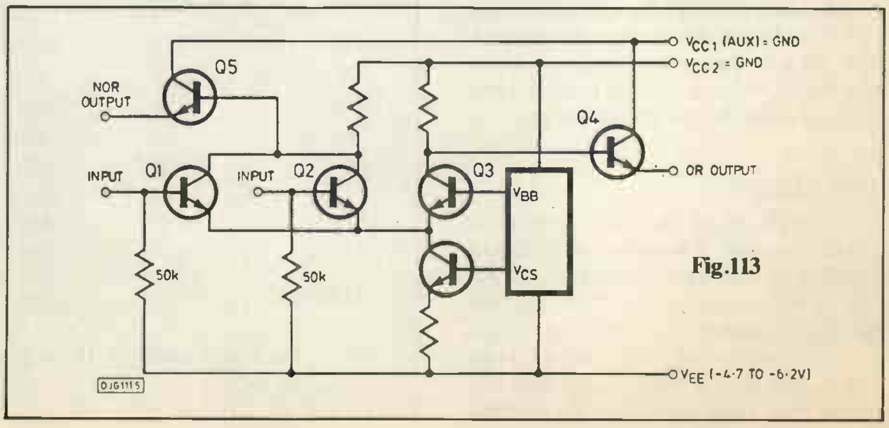


Fig.113

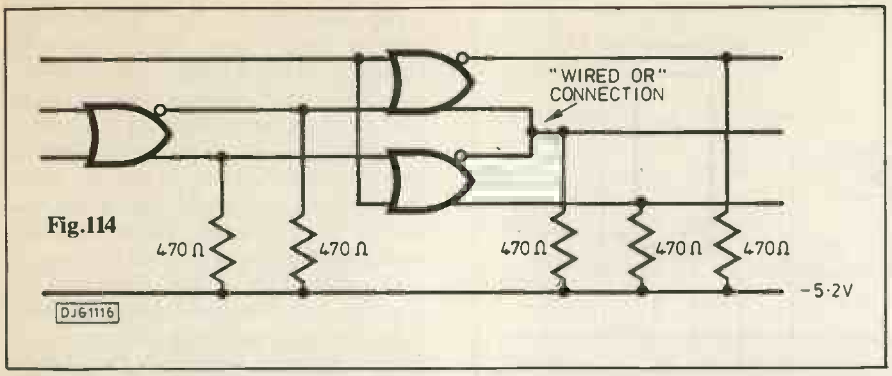


Fig.114

10101. This is in contrast to ttl in which both NAND and NOR logic functions are iwdely used, but in which NAND predominates. The fact that the standard ecl gate has true and complement outputs, wired OR capability, and is of the basic OR configuration, means that efficient ecl designs are very different in form from ttl designs for the same function.

TERMINATIONS

When ecl is used in fairly high speed applications in small systems where the interconnections are short, then simple pulldown resistors on the outputs as illustrated in Fig.114 are quite adequate.

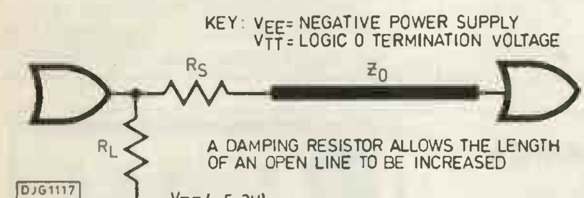


Fig.115

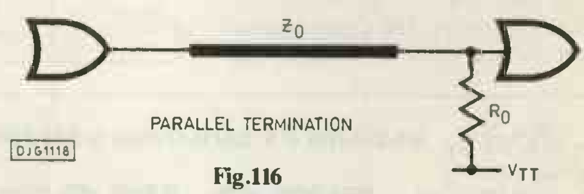


Fig.116

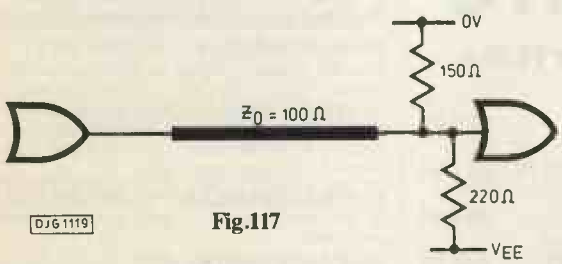
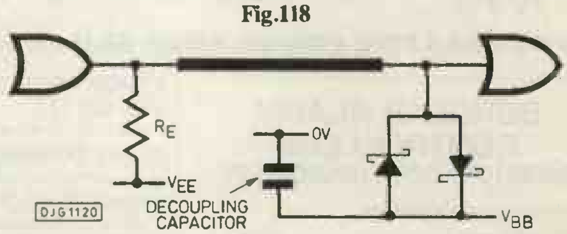


Fig.117

Fig.118



However, where the ultimate speed is required and/or where interconnections are long, it is normal to design ecl printed circuit boards with an earth plane and transmission line connections. In this context transmission lines are tracks whose width is calculated to give the correct impedance so that the signal is propagated across the pcb without distortion or reflection at the far end. The far end of the transmission track is then terminated with a 50Ω to 100Ω termination.

The ecl gate is not able to source enough current from its output to drive the correct logic levels into a termination of 50Ω to −5V, so instead a pair of resistors is used to give a termination whose not impedance is 50μ and whose nominal voltage is equivalent to logic 0. As a better alternative, the transmission line may be terminated by a resistor of the correct impedance connected to a bias supply generated by an on chip bias voltage generator, such as that on the 10116. This minimises the total power dissipation, as well as providing a termination voltage which tracks the logic levels of the chips.

Figs.115 to 117 show various matched track termination schemes, including a matched sending end to prevent reflections from the receiving end being reflected once again from sending end to receiving end. If such reflections were allowed to take place then a clocked circuit could count twice (or more) when only one clock pulse was sent. Fig.118 shows an alternative strategy in which Schottky diodes are used to clamp the end of the transmission line. This has the same aim as the matched terminations, ie to damp rings which result from signals being reflected back and forth along the line.

Interconnections using transmission line tracks are fine for on-board use, but obviously this technique cannot be extended to connections between boards. In order to send signals between boards, with minimum distortion, balanced transmission is often used. Special balanced line transmitter/receiver ics are available for example the 10116 in 10000 series ecl and these are used to send the signal along a twisted pair of wires from one board to another. Though these chips are true differential logic buffers, they may be used as single ended to differential or differential to single ended converters. To facilitate their use in the former application, a bias voltage is included on the chip, and is connected to one of the pins. In single ended to differential conversion applications, the bias voltage is connected to the unused input. The bias voltage could be generated by a potential divider, but the bias voltage generated on the chip has the same drift with temperature as the logic levels on chip, so the whole system tracks and works better than if a potential divider were used to generate the bias voltage.

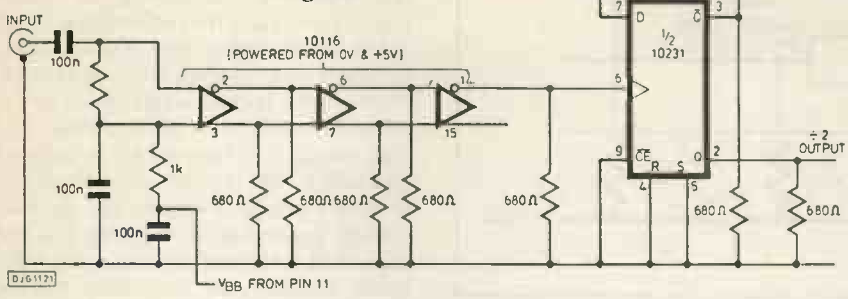
The presence of the bias voltage on the 10116 is also helpful for frequency meter applications. If the bias voltage is connected to one input and the signal to the other, the 10116 forms a very effective input stage for a high frequency counter. This may seem strange, because these ics are logic chips, but between the logic levels the ics work in a more or less linear mode, and have a worthwhile amount of gain. By cascading several 10116 parts a low level input signal can be amplified to full ecl logic levels. The resulting signal may then be fed to an ecl frequency divider to reduce the frequency to something suitable for use with ttl. An example of this sort of application is shown in Fig.119.

POWER

One interesting fact about ecl is that, in contrast with ttl, there is little change in power supply consumption as outputs switch. TTL circuits may draw sharp pulses of 50mA while switching, but when an ecl output switches there is simply a change in the current flowing down the termination resistors commensurate with the change in voltage on the output. If complementary outputs are used, and have the same value pulldown resistors, then the changes in current cancel out.

From this it is tempting to believe that

Fig.119



decoupling of the power supply is not necessary, and indeed circuits can work with poorer decoupling than would be possible with Schottky ttl. However, there are local changes of load current even if the overall current remains roughly constant, so to avoid puzzling intermittent problems it is still best to decouple the power supply properly.

ECL gates are expensive, complex logic functions doubly so. For this reason, in applications requiring a monostable, the circuit shown in Fig.120 is sometimes used. This performs the monostable function adequately and is reasonably accurate. When a clock pulse is applied the flip flop switches over. The capacitor then charges via the resistor until the chip is reset. The charging time taken by the capacitor in reaching the reset voltage sets the monostable period.

This is probably sufficient on the subject of ecl for general interest. To sum up, emitter coupled logic is a non-saturated logic which consumes a lot of power and

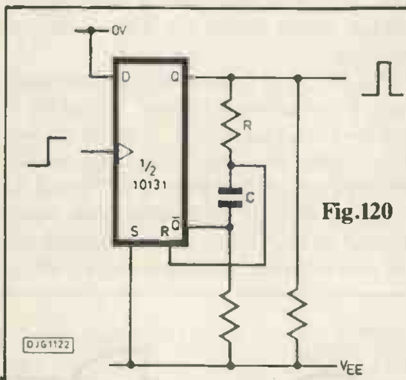


Fig.120

is expensive, but has very low gate propagation delays and rapid switching. Though it is fast, because it runs with low logic voltages, it does not tend to radiate a lot of interference. Because it runs at a low impedance, it is not very susceptible to outside interference. In fact, if it were cheaper and consumed somewhat less power, its admirable qualities would probably lead it to be more widely used.

This sums it up for logic families. I do not intend to delve into microprocessor chips as this is a specialised subject all on its own. In two month's time I shall start taking a look at opamps. PE

NINE TO FIVE

A cautionary tale for battery users – A telephone caller asked if IC1 of my Event Counter of July 87 should get hot.

Questions sometimes bring unexpected answers. He'd omitted the regulator chip IC3 and plugged his 9V battery straight into the circuit. The counter failed to work. Finding IC1 on the verge of self-cremation, my caller then tried bringing the power via IC3, but still nothing worked.

Unfortunately, in common with ttl and many other chips, IC1 has a voltage limit of 5V. Most chips will tolerate a fraction or two above their specified working voltage, but not nearly 100% over. He'd learned the hard way that nine into five will not go.

Never significantly deviate from specified power levels without checking the specs for all parts of a circuit. Ed.

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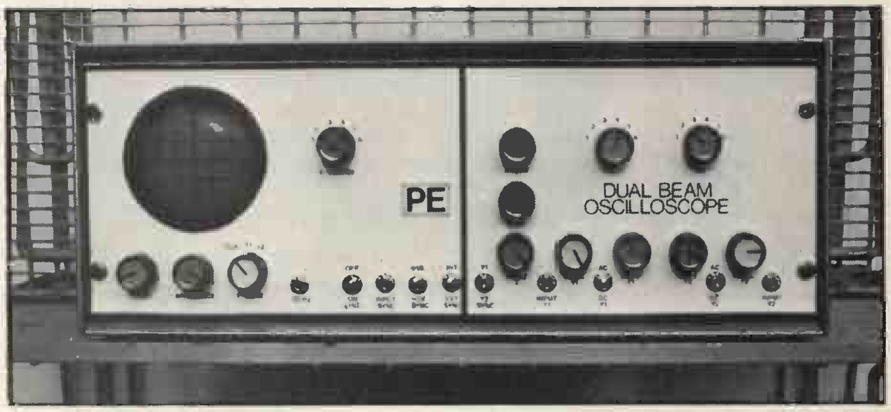
PART TWO BY JOHN BECKER

SCREENING AN X-RATED SYSTEM

This month's instalment of our major project describes the time-base generator and how the X-axis scan is controlled.

Last month we saw how an electron beam was produced within a cathode ray tube, accelerated, focussed and caused to impact on a fluorescent screen. Following construction of the power supply, we saw how manually controlled pots could deflect the beam spot around the screen. Obviously, for the scope to have any meaningful purpose the spot manipulation must be under automatic deflection control.



BEAM SWEEPING

First we need to put the beam under repetitive horizontal movement, progressively changing the potential on the X plate pairs so that the beam traverses the screen from one side to the other, conventionally moving from left to right. On reaching the right hand end of its sweep the beam then has to be returned to its left hand origin and start across once more.

While the beam is sweeping across it can additionally be deflected up or down by the potential on the Y plate pairs. When the Y axis potential is reacting to an ac waveform it will be seen from Fig.14 that the horizontal sweep must be timed so that the spacing between the waveform peaks is neither too close, nor too wide since we usually need to observe only a few cycles of the Y signal. Consequently, we must be able to vary the sweep speed to suit different signal frequencies.

Naturally, the vertical deflection of the beam will occur irrespective of the direction of the sweep. This will result in the signal being traced on the screen in both directions and could lead to visual display confusion, such as in Fig.15.

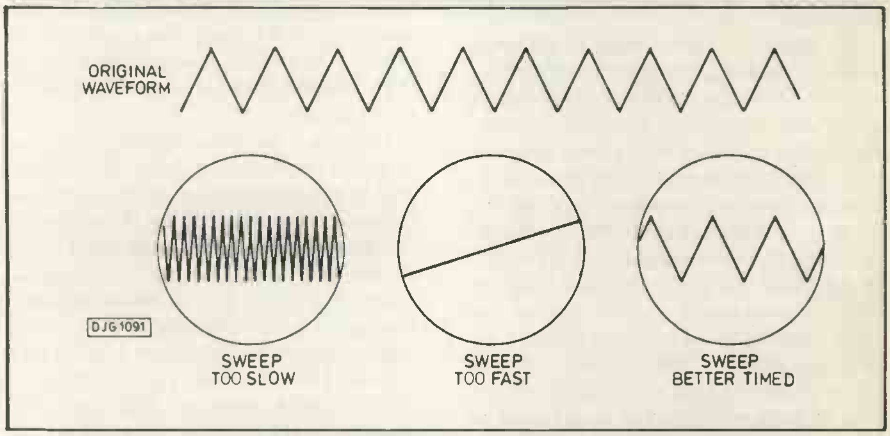


Fig.14 *Effect of using different sweep speeds for the same sampled waveform.*

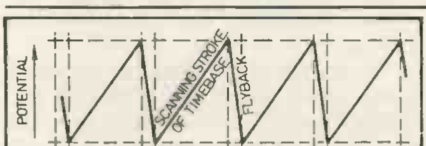


Fig.16 *Idealised timebase sawtooth waveform.*

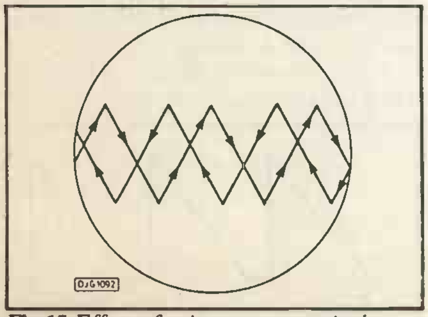


Fig.15 *Effect of using a symmetrical X-axis sweep with an ac waveform on the Y-axis.*

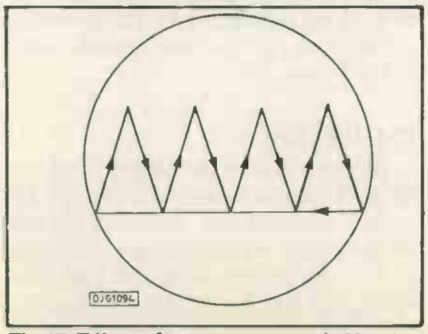


Fig.17 *Effect of using a sawtooth X-axis sweep with an ac waveform on the Y-axis.*

What we need is to sweep the beam across the screen from far left to far right at the required rate, then to return it rapidly to the left so that during the return its vertical deflection has insufficient time to change significantly. Therefore, the sweep control waveform needs to be a sawtooth, as in Fig.16, or some other form of retriggered ramp. We shall also see later that the flyback trace, shown in Fig.17, can be suppressed.

Ideally, for most waveform examinations, each sweep across the screen needs to be timed so that each waveform display starts at the same point of the vertical trace. Thus we need to synchronise the X and Y traces to avoid further visual confusion, such as that seen in Fig.18.

BASIC TIME BASE

The general term given to the horizontal sweep oscillator is time base, and as we have just seen, in its simplest form it is just a sawtooth waveform generator.

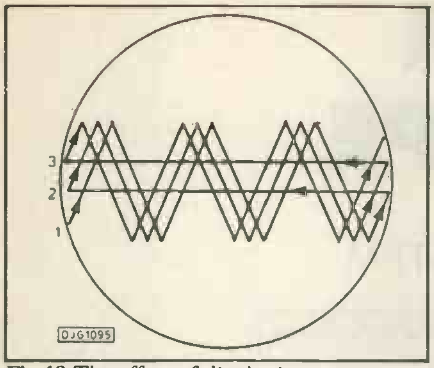


Fig.18 *The effect of displaying unsynchronised X and Y signals.*

There are many ways of generating sawteeth and the basic one chosen for this project is shown in Fig.19.

Assume that the output of IC2 is low, and that C1 is discharging at a rate set by VR1. In response, the output of IC1 progressively increases until the voltage at the positive input to IC2 rises above that on its negative input. Being configured as a comparator, the output of IC2 now goes high, immediately recharging C1 via D1. Simultaneously, the output of IC1 goes low thus resetting IC2 to its low output state, whereupon C1 again starts discharging via VR1, and so the cycle continues.

By using a switched bank of different value capacitors, plus the variable pot, a very wide variety of frequencies can be generated. There is a problem, though, due to the response time of the opamps. Although the threshold trigger voltage remains constant irrespective of the frequency, the time taken for the opamps to reset results in the output of IC1A falling to different levels for different frequencies. Consequently, the low end of the ramp terminates at a higher voltage for slow frequencies than it does for fast ones. Even the high speed LM6361 suffers from this effect and was found to have no greater merits for this oscillator than the less expensive TL082. Standardisation of the ramp amplitude is achieved by the inclusion of an additional gate and trigger circuit. The full time base circuit diagram is shown in Fig.20.

RAMP GENERATOR

The configuration around IC1A and IC1B forms the retriggerable ramp generator. Capacitors C1-C6 are switched by S1A to select the basic ramp rates and VR2 provides intermediate rate variation control. The retriggering and amplitude standardisation, though, is conditional upon several other circuit factors.

Assume for the moment that the right hand end of VR2 is simply taken to the negative line, providing a path for discharging the selected capacitor. Also assume that the capacitor is now fully charged and, therefore, that the output of IC1A is low. This output voltage is taken via VR1 to TR3 and is low enough not to turn on the transistor. Consequently, the threshold bias voltage applied to pin 6 of the comparator IC1B comes via R7 and D2, and the output of IC1B is correspondingly held low.

As the capacitor discharges, the output of IC1A continues to rise, and passing through D1, eventually crosses the comparator's threshold level. IC1B trips and its output goes high charging the capacitor via D3. The output of IC1A goes low, but D1 prevents IC1B from being reset by this change. Only when the output of IC1A has fallen low enough to turn off TR3 will the comparator threshold level be changed by the higher voltage from R7. At this point IC1B will revert to its original low-output state. The overall result is that with VR1 correctly set, the output of IC1A will fall as low as its nature can ever allow, and stay there until IC1B has been reset.

SYNC RETRIGGERING

We assumed above that the right hand end of VR2 was taken direct to the negative line. In fact, it is only taken low when either D5 or D6 are biased to allow it. This routing is dictated by the requirements for synchronising the ramp to the waveform being monitored. It also ensures that the ramp will eventually be retriggered even if a sync pulse does not occur, in the absense of an input signal for example.

Let's look at sync triggering first and examine the circuits around IC2A, IC3A and IC4. Ignore the automatic retriggering circuit around IC2B for the moment.

The sync trigger can come from either of the two Y-input amps, or from an external source. In the latter instance, the signal is first decoupled by C17 and restricted to a maximum of ±5V by R18, D8 and D9. S3 selects between internal and external sources, VR5 sets the required level, and then S4 selects the trigger polarity by switching IC4 between inverting and non-inverting modes.

The output of IC4 produces a positive-going pulse across C18, D18 and R23 which is taken to the clock input of the flip-flop IC3A. When the pulse is of sufficient amplitude IC3A receives it as a clock pulse, whereupon its pin 2 goes low and remains so until reset. For as long as IC3A pin 2 stays low, so the right hand end of VR2 is held low via D5, providing a discharge path for the selected ramp control capacitor.

INHIBITED

After the end of the ramp flyback and when IC1B pin 7 has been reset low, the output of IC2A, an inverting Schmitt trigger, goes high and a positive-going pulse is generated across C7. This pulse resets the flip-flop IC3A and its pin 2 goes high, so inhibiting the capacitor discharge path via VR2. The ramp will not start again until IC3A is triggered by the next clock pulse from IC4B. Each X-sweep trace will thus commence at the same relative position of the incoming sync waveform.

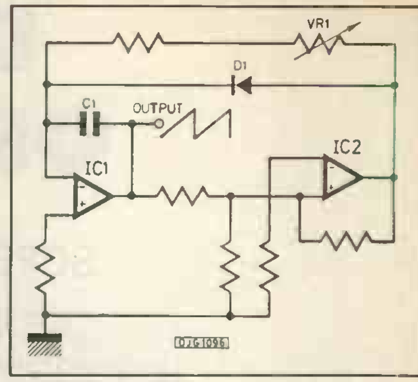


Fig.19 *Basic sawtooth generator.*

AUTO RETRIGGERING

It is frequently preferable to have the X-trace constantly sweeping across the screen even in the absence of an ac input signal, when monitoring dc levels for example. So it's necessary to have an alternative ramp retrigger source that takes over if the sync signal is missing. This is where the circuit around IC2B comes into play.

When IC3A pin 2 goes high, current flows through R9 and into the capacitor selected by S1B. The capacitor charges until the trigger threshold of the Schmitt trigger IC2B is passed. Its output at pin 4 then goes low, and with S2 closed, the discharge path for VR2 is available through D6. The X-ramp can now restart even though IC3A has not received a sync pulse.

The capacitor selected by S1B will stay charged for as long as IC3A remains untriggered, so IC2B will continue to provide the discharge path, thus allowing continuous ramp repetition. When a sync pulse is received by IC3A, the capacitor selected by S1B will discharge via R10 and D7, so that the effect of IC2B is inhibited. The relative values of C1-C6 and C8-C13 have been chosen to allow a reasonable opportunity for a sync signal to be acted upon before the automatic retriggering can be initiated.

With S2 open, the ramp will only be triggered each time a sync pulse is accepted by IC3A. If a pulse is not received, the beam spot will remain at full left hand deflection.

Fig.21 shows a typical retriggered ramp trace.

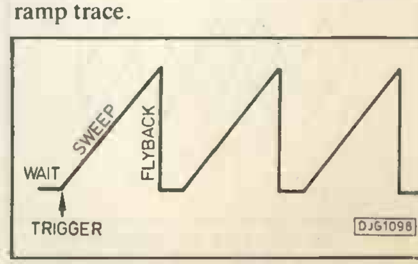


Fig.21 *Retriggered ramp trace.*

RAMPING THE CRT

The ramp output voltage from IC1a is insufficiently great to adequately drive the X-deflection plates on the tube. These need voltages in a similar range to the final anode voltage. In the days of the early scopes I mentioned in part one only valves could handle the high voltage needed to drive the plates. Now semiconductors are much hardier and can readily handle very high voltages. The tube has nominal deflection factors of 21V per cm for one set of plates, and 37V per cm for the other. Since the tube is 7cm in diameter, we need plate voltage differential swings of around 147V and 259V respectively in order to sweep the full face. By putting the twin plates under push-pull deflection control, the actual swing for a single plate can be roughly halved. We still need, though, to allow for manually shifting the trace around the screen. In practice, a maximum ht line voltage of +250V is satisfactory and so the drive transistors have been selected to withstand the voltage. They will, in fact, withstand a maximum of 300V across them, but it is prudent not to let the ht power line get too close to this limit.

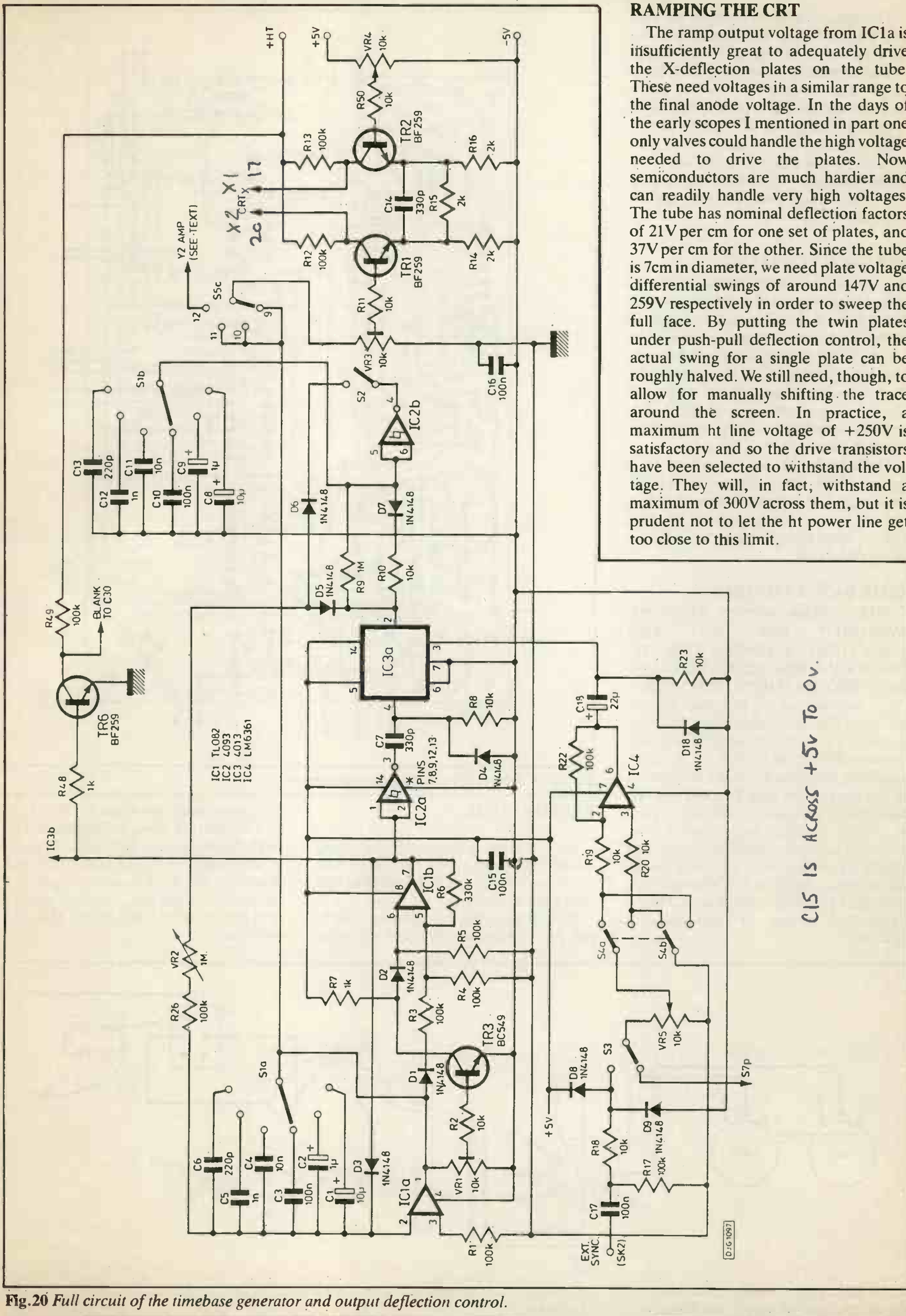


Fig.20 *Full circuit of the timebase generator and output deflection control.*

The ramp voltage is brought via VR3 and R11 to TR1. VR3 should be set so that the output at the collector of TR1 swings smoothly across the full ramp range. The collector output is taken direct to one of the X-plates. The other X-plate is connected to the collector of TR2, which is under control of VR4. The emitter coupling between TR1 and TR2 introduces push-pull bias and by varying VR4 the screen trace position can be adjusted at will.

FLYBACK BLANKING

As mentioned earlier, although the X-sweep trace rapidly flys back to the left hand side, it is still possible to see it. However, the tube characteristics allow for the beam to be blanked out if a negative voltage is applied to the control grid. With reference to the cathode voltage, if the grid has a voltage of at least –50V applied during fly back, the trace will be blanked out.

The achieve this, the output of IC1B is taken to TR6. When the output of IC1B goes high, TR6 is turned on generating a negative-going pulse across C30 (see Fig.5), with D17 limiting the positive-going pulse edge.

TIME BASE ASSEMBLY

THE POWER SUPPLY MUST BE SWITCHED OFF AND THE CAPACITORS ALLOWED TIME TO DISCHARGE BEFORE MAKING ANY ASSEMBLY OR WIRING CHANGES.

The pcb layout for the time base is shown in Fig.22. Double-check that you correctly orientate the electrolytics and semiconductors. Note that S1 is a pcb mounting rotary switch and it is soldered to the *back* of the pcb. You will need to take special care when soldering its pins to ensure that all are properly connected. The bush of this switch will ultimately be used to hold the entire board on the front control panel. Note too that the Y-axis pcb is also fixed on the front panel by means of pcb-mounted switches.

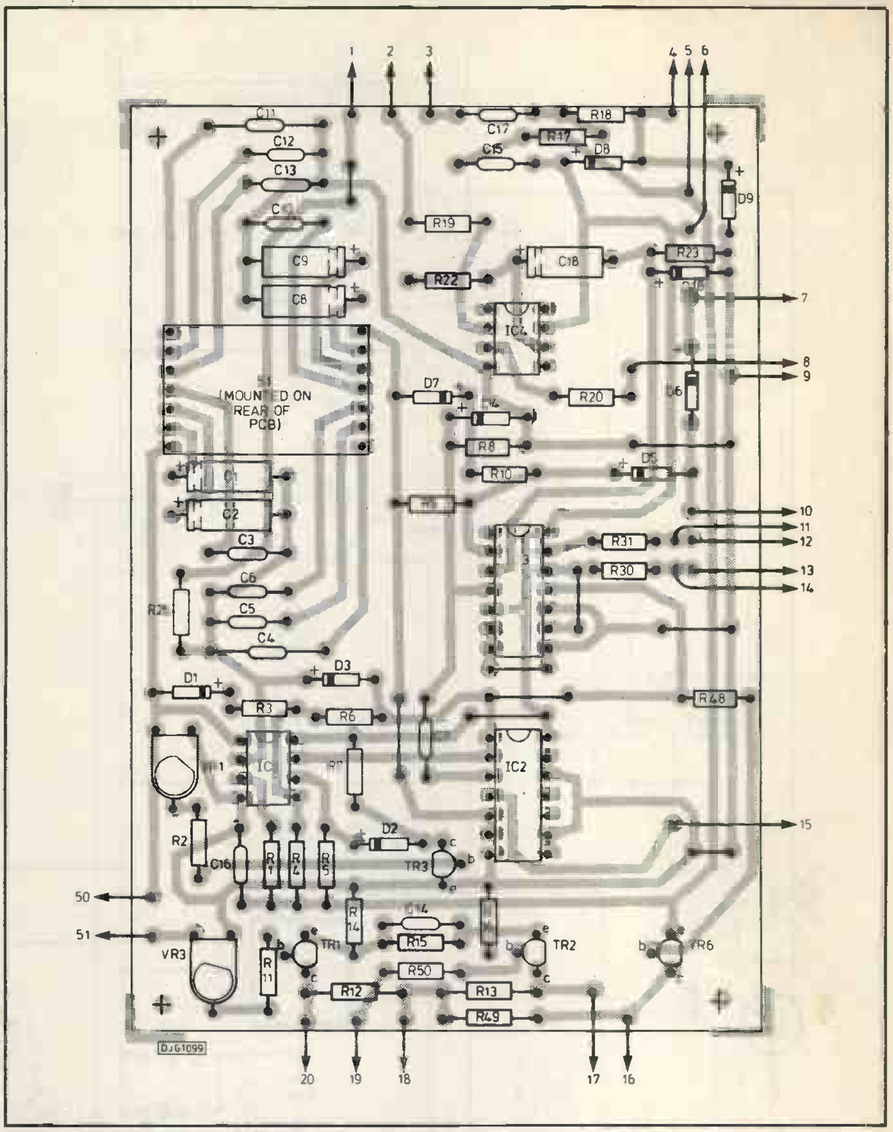


Fig.22 *PCB layout for the timebase generator.*

TESTING TIME

Do not connect the completed board to the tube until a few tests have first been carried out, starting with the basic time base oscillator.

Referring to Fig.24, connect VR2 to pcb pin 1 as shown, but take the other pot connection, not to pin 10, but to the –5V connection at pin 9. Connect the fly back blanking from TR6 to C30 on the power supply pcb and temporary link points 50 and 51. Connect the pcb±5V power lines to the psu, but don't yet connect the +250V line. Insert IC1 and switch on.

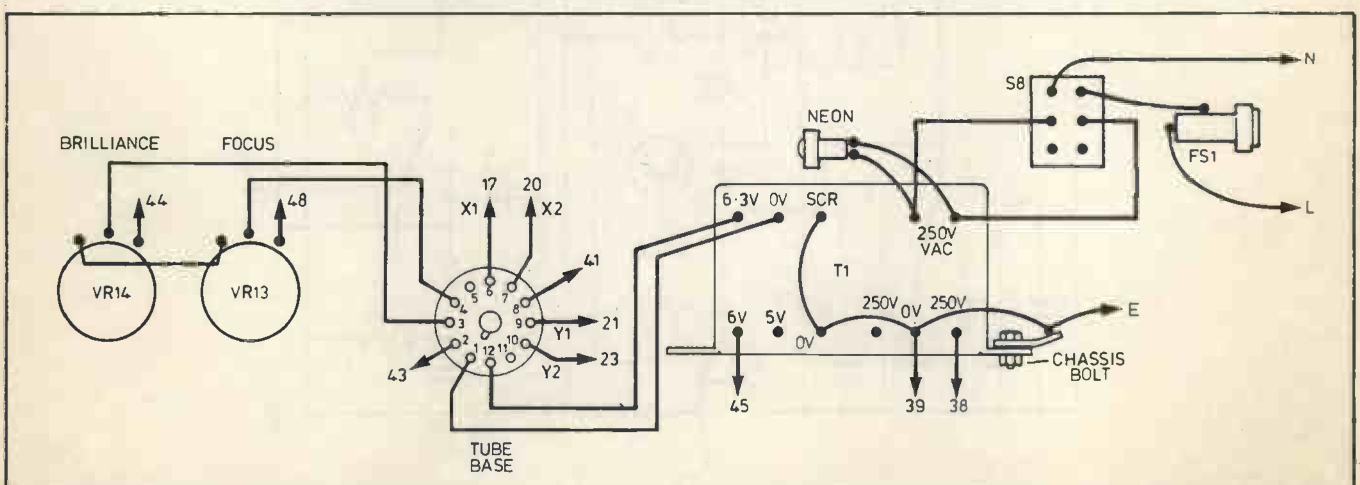


Fig.23 *Final power supply and tube control connections.*

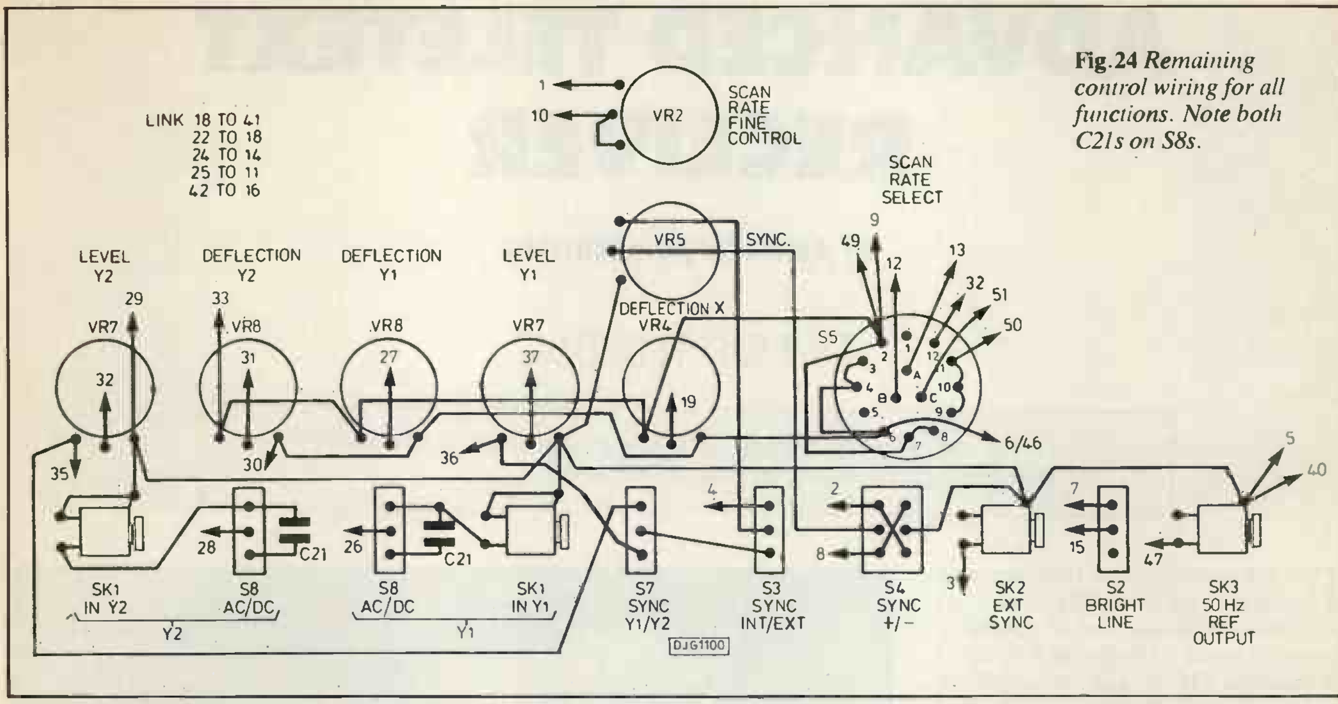


Fig.24 *Remaining control wiring for all functions. Note both C21s on S8s.*

COMPONENTS
OSCILLOSCOPE TIMEBASE

RESISTORS

R1,R3-R5,R12, R13,R17,R22, R26,R49	100k (10 off)
R2,R8,R10,R11, R18-R20,R23, R50	10k (9 off)
R6	330k
R7,R48	1k (2 off)
R9	1M
R14-R16	2k (3 off)

All resistors ¼W5% carbon

MISCELLANEOUS
Knobs (4 off), Phonosonics pcb 290A 8-pin ic socket (2 off) 14-pin ic socket (2 off), 3.5mm jack socket.

CAPACITORS

C1,C8	10µ 25V electrolytic (2 off)
C18	22µ 16V electrolytic
C2, C9	1µ 63V electrolytic (2 off)
C3,C10,C15-C17	100n polyester (5 off)
C4,C11	10n polystyrene (2 off)
C5,C12	1n polystyrene (2 off)
C6,C13	220p polystyrene (2 off)
C7,C14	330p polystyrene (2 off)

POTENTIOMETERS

VR1,VR3	10k skeleton (2 off)
VR2	1M mono rotary
VR4	10k ~~100k~~ mono rotary
VR5	10k mono rotary

SEMICONDUCTORS

D1-D9, D18	1N4148 (10 off)
TR1,TR2,TR6	BF259 (3 off)
TR3	BC549
IC1	TL082
IC2	4093
IC3	4013
IC4	LM6361

SWITCHES

S1	2p 6W pcb mounting
S2,S3	min spdt (2 off)
S4	min dpdt

The scope tube and base are available from Langrex Supplies Ltd, 1 Mayo Road, Croydon, Surrey CR0 2QP. 01-684 1166. (This new address and telephone number replace those quoted last month)

Connect a multimeter across IC1A pin 1 and the −5V line. With S1 set for slower speeds, rotate the wiper of VR1 until the meter shows that the oscillator is running. This will be apparent from seeing the meter needle slowly rise, then rapidly fall back. Check that VR2 can vary the rate. The fast ramping selection by S1 will not be too apparent on a meter, but this can be checked once connection to the tube has been made.

Now correctly connect VR2 to pcb pin 10, wire in S2, then insert IC2, IC3 and IC4. Continue monitoring IC1A pin 1, switch on S2 and check that repetitive ramping still occurs as before. Switching S2 open should stop the ramp. Temporarily connect the output of the 50Hz generator from the psu pcb to arrow S7p of S3. With S3 in either position, and VR5 fully turned up, the ramping should restart.

Switch off, connect up VR4 and bring the +250V line from psu pcb pin 41 to time base pcb pin 18. Switch on and monitor the +250V line on a meter. If necessary, readjust VR11 until +250V is obtained.

Next monitor the collector of TR1, switch the ramp to a continuous slow rate and adjust VR3 until the meter needle can be seen swinging back and forth with a midpoint around the 200V mark. Further adjustment can be made following connection to the tube. Now monitor the voltage swing at the collector of TR2 and check that VR4 is capable of varying the swing range up and down, then set VR4 for a midpoint swing of about 200V.

TUBE CONNECTION

Before connecting the X-trace leads to the tube base, first adjust the four temporary deflection pots, discussed last month, and position the beam spot in the centre. Then completely disconnect the two temporary X-axis pots, but leave the two Y-axis pots in place. Take the X tags of the tube base to their respective pcb points (pins 17 and 20).

Upon switching on again adjust VR4 until the horizontal trace is central across the screen. Now adjust VR3 until the trace length almost crosses the full screen width, readjusting VR4 if necessary.

Switching S1 between timing ranges, it may be apparent that the trace starts at different screen positions. If so, adjust VR1 until the start points are more uniformly matched. If you find the ramp reluctant to start at the slowest setting, slightly readjust VR1. Now readjust VR3 until the trace extends slightly off the screen to both sides. Recheck the +250V line and if necessary readjust VR11.

That concludes the time base generator, but I regret you'll have to wait until next month for the Y-axis controls and dual-beam splitter. **PE**

NEXT MONTH
Details of the input amplifiers and guidelines on using a scope.

ADVANCED TELETEXT RECEIVER

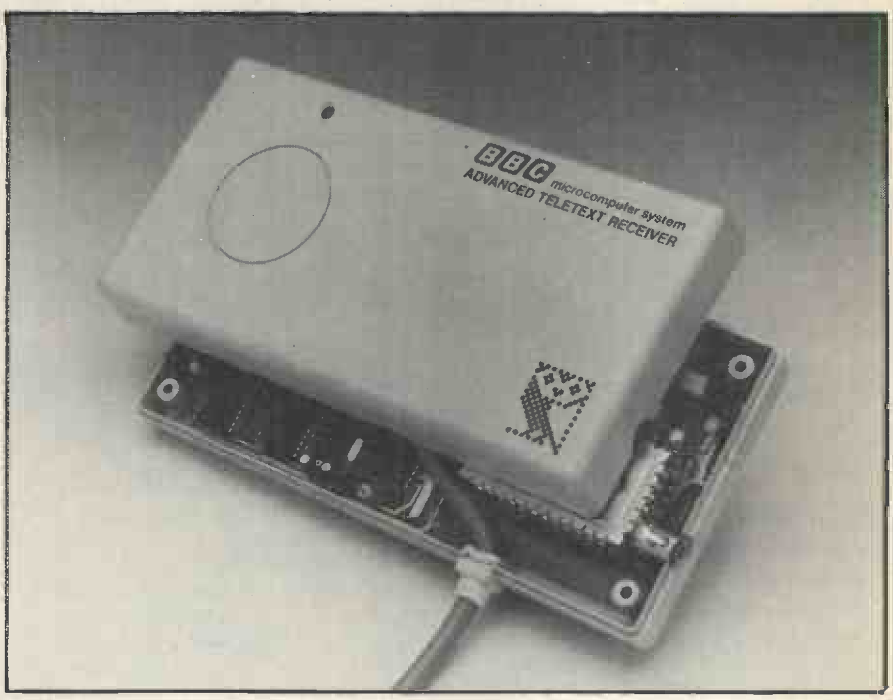
BY ANDREW ARMSTRONG

TV FOR THE BBC

A first step towards letting your computer watch tv for you – and having something to talk about later.

The Advanced Teletext Receiver is an accessory for the BBC range of computers to permit the computer to display teletext (Ceefax and Oracle) information. It is also intended to download telesoftware – computer programs transmitted on Ceefax on BBC2.

The unit is compact and is housed in a smart plastic case. It measures 220 x 110 x 45mm, and can be wall mounted or free standing. It is powered from the external power socket on the Beeb, and plugs in to the user port.



IN THE PLASTIC

My review copy arrived well packed in a cardboard box padded with foam. With its attractive looking handbook and smart case it looked encouraging.

The initial instructions of how to make it function were straightforward and simple to follow. There is a rom which must be installed, and the instructions are quite precise about which sockets it may or may not be installed in. The bus connector can physically plug in either way round, but the instructions make enough play of this that no one has any excuse for plugging it in the wrong way round.

About ten minutes after opening the package I was ready to switch on. About half a second after I typed in * TELETEXT the monitor displayed the index on page 100. The channel tuning information is stored in non-volatile memory in the teletext receiver, and it had clearly been programmed before dispatch for channels in use in my area.

The tuning procedure is in any event straightforward, as I found when I tuned to an adjacent regions ITV service.

Operation of the unit as a basic teletext reeceiver is very much like using a television for the same purpose. Of course, you can't view the television programme at the same time even if you are using a television receiver as the monitor. This means that the you cannot make use of subtitles broadcast with some programs, even though the "Subtitles" function is included in the rom which operates the system. I gather that this function is included only because it is in the teletext specification.

As a basic teletext receiver, operated in the "terminal mode", the unit has more facilities than the average television set. It can store pages of information for display later. It also anticipates the user turning to the next or previous page in a sequence, or to linked pages, and stores them ready for use.

LOAD YOUR PROGRAM

If you have a storage device such as a disk drive attached to your Beeb, then the teletext receiver can be used to download telesoftware to it. The BBC transmits a number of Basic programs, machine code programs, and text files for use by the computer. These are transmitted on pages above 700 on BBC2. This is where the manual starts to fall down, although to be fair it is not worse than the general standard of BBC Micro information at this point.

In testing the telesoftware function, I simply followed the instructions in the handbook to see what would happen. This is a procedure which often works and leads to a quick understanding of how to operate the function. It didn't work, of course, because I had unplugged the disk drive's power plug to plug in the teletext adaptor. There was no "currently selected filing system", as the manual says, and therefore no means to store the telesoftware. In my innocence I had thought that it would store downloaded information in memory, but no such luck.

In fact, inspection of the manual shows no mention of "currently selected filing system" in the section on downloading telesoftware; this is only mentioned in the introduction. But then, one should instinctively know . . . Perhaps if the seection on downloading telesoftware had said something similar to: "To download telesoftware, select a storage system (disk, tape, or network) before entering terminal mode" it would have been clearer. To avoid needing to consult the Beeb's own manual, the further comment "for example *DISK" would have helped.

BASIC

"How do I make it do something?" I asked the man at GIS. There appear to be two main ways. The first is to use a T connector to connect two loads to the Beeb's output socket and use a disk drive at the same time as the teletext receiver. The other is to write a Basic program to grab pages of information and transfer them to memory. "There is an example on page 71" I was told. I was warned about the error on one parameter, where a 1 becomes a 0 in one place, but not about the other misprint or about the need to add PROCedures from other pages to make the program work. I am informed that the manual is to be reprinted with some corrections in the near future, and that meanwhile a sheet of errata is to be sent with the manuals.

It did eventually claim to have loaded some telesoftware, but it was not possible to do anything with it, in part because the screen area in operation had been reduced to three lines of text by some side effect of the program, and partly because there was no obvious means of using software stored in memory anyway.

The later acquisition of a suitable connector to power the disk drive as well as the teletext adaptor did permit the downloading of some software, and a text file. Some of the programs worked and some complained that the BBC model B had not got enough memory, which was not the fault of the teletext adaptor. One program which I thought clever used the teletext adaptor to access information on exchange rates, and then do up to date currency calculations for any selected country.

With a disk drive, it was as easy to download software as it had been difficult before. The file is automatically stored on disk, under the name with which it is transmitted. A general word of warning here; do read the notes on the programs before using them, because many programs are in pairs, the first one being used to provide instructions and then call a second program.

It seems clear that the convenient way for most people to use telesoftware would be to have a disk drive either separately powered or running from the Beeb via a T adaptor, or (at a pinch) a cassette recorder with its motor controlled by the Beeb. To make use of the telesoftware without a storage device connected you would need to know your way around the operating system, the osword and the osbyte etc, as well as I know my way to the local boozer.

The Beeb is an idiosyncratic computer, and it is likely that many Beeb enthusiasts will already have this knowledge. If you do not, you would do well to have a disk drive and the means to power it at the same time as the teletext receiver.

I am told that a version of the teletext receiver to suit IBM PC compatible computers will be out soon (probably by the time this sees print) and that the BBC are to transmit telesoftware for PC compatibles. As all PCs have disk drives, storing the downloaded information should present no problems. Equally, the use of an MSDOS disk based system opens the door for an even more comprehensive control software package. It should be easier to control with a more generic form of Basic, or even from BATch files.

BBC Advanced Teletext Receiver is priced at £149 and is available from General Information Systems Ltd, Croxton Park, Croxton, Cambs, PE19 4SY.

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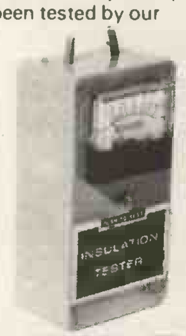

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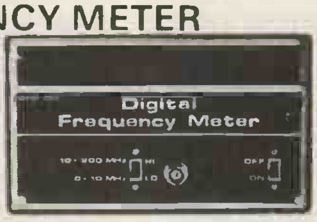

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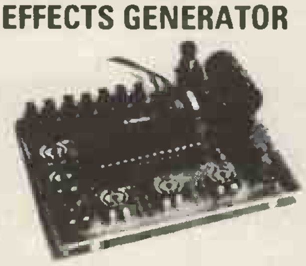

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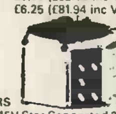

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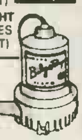

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WIRE BARGAIN – 500 metres 0.7mm solid copper tinned and p.v.c. covered. Only £3 plus £1 post. Ref. 3P31 – that's well under 1p per metre, and this wire is ideal for push on connections.

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

DIGITAL ELECTRONICS

BY OWEN BISHOP

PART 4 – DIGITAL CIRCUITS GATING THE FLIP-SIDE

Logic circuits are fundamental to digital control, but, like all digital electronics, they're all just switches at heart. This month we look at two types: flip-flops and counters

In the first part of this series there was a circuit that performed logic. It told you whether or not you would be able to watch the Six O'clock News on tv. This was a very trivial example, and it is not likely that you would actually want to build such a circuit. But it illustrates the idea that it is possible to build circuits to perform logical operations. The 'tv' logic circuit used ordinary switches but, to use logic that will control electronic circuits, it is preferable to use logic gates of the type we described in Part Two.

LOGIC SYSTEMS

The main sections of a typical logic system are shown in Fig.1.

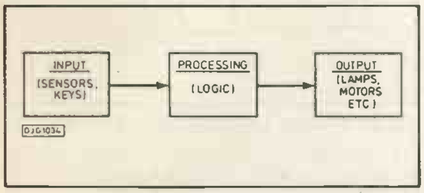


Fig.1 *Sections of a typical logical system.*

1. **Input** – the logic must be told what is happening in the world outside. In a manually controlled system, this section consists of switches, buttons or a keyboard to receive commands from the operator. An example of this was the 'Six O'clock News' logic system, which was operated by two switches. In an automatic system, such as a washing machine controller, the input section comprises sensors which detect water level, for example, or water temperature. There are also push-buttons or switches for selecting the required washing cycle and telling the machine to start.
2. **Processing** – this is the part of the system that performs the logic. Given a certain combination of inputs, it controls the actions of the output devices.
3. **Output** – this consists of output devices such as indicator lamps, sirens, heaters, motors and pumps.

These three sections or stages – input, processing and output – are found in almost all logical systems, from the simplest to the most complex. Incidentally, don't confuse the input and out put **Sections** of *the system as a whole* with the input and output **terminals** of *parts of the system* such as sensors or logic gates.

SECURITY LOGIC

We will use the principle outlined above to design a security system. The system is to switch on a siren if a certain door is opened at night. During the day the door may be opened without sounding the siren. Two logical inputs are needed:

* *light sensor* – to check for daylight or darkness.

* *door sensor* – to check if the door is open or shut.

Later in this series we shall study some sensor circuits that could perform these functions but, for the moment, we shall adopt the 'black box' approach. Just think of each sensor as being a circuit with a logical output (1 or 0), as in Fig.2.

Before designing the processing section of the security system, we must consider the output device it has to control. In this example, the requirements are simple. The output device is a siren. We need a transistor to switch on a small audible warning device, or to switch on a relay to activate a high-power siren. Fig.3 shows its input conditions.

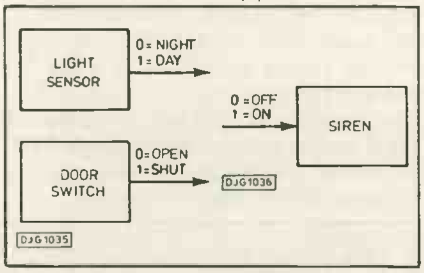


Fig.2 *(left) Input and output.*
Fig.3 *(right) Devices for the security system.*

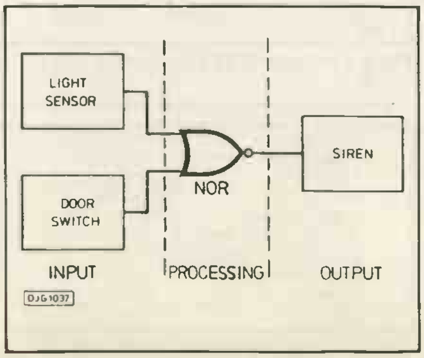


Fig.4 *The security system.*

Now for the interesting part, the logic that receives inputs from the input devices (Fig.2), performs its logical operations, and sends its output to the output device (Fig.3). The best way to set about the design is to set out the requirements in a truth table – a table showing what we want to happen. The table below lists all possible combinations of inputs:

Inputs		Output
Light sensor	Door sensor	
0	0	
0	1	
1	0	
1	1	

We fill in the output column to show what we want to happen for each combination of inputs. We want the siren to sound (output to siren = 1) if it is dark (light sensor output = 0) and if the door is open (door sensor output = 0). Under all other conditions the siren is to be silent (output to siren = 0). This is the truth table of our requirements.

Inputs		Output
Light sensor	Door sensor	Siren
0	0	1
0	1	0
1	0	0
1	1	0

Readers who have Part 2 handy will see that this is the truth table for nor. Therefore, a single nor gate performs the logic required. Fig.4 shows the complete circuit.

Now let's extend the system, to give greater security. We will add an extra sensor in the form of an alarm button that anyone can press at any time of day or night to make the siren sound. Fig.5 shows its output. Can you work out how to add this alarm button to the system?

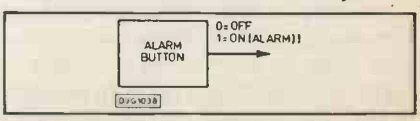


Fig.5 *An additional input for the security system.*

Check on your design by wiring up the circuit with logic gates and trying all possible combinations of inputs. (Answer on p.40).

Now can you re-design the system so that the alarm button and door sensor only operate during the night? (*Hint:* you may need to invert one of the sensor outputs).

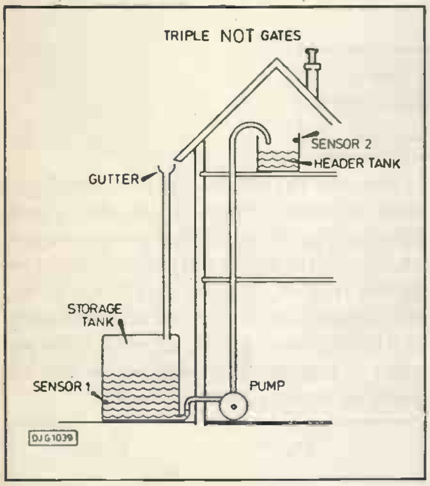


Fig.6 *Water pumping system.*

Finally, here is another logic design problem. A large storage tank is filled by rain water from the roof (Fig.6). An electric pump is used to pump water from the storage tank into a header tank in the loft. The pump must keep the header tank full, as long as there is water available in the storage tank. The pump must not operate to overfill the header tank or if the storage tank has too little water in it. The tanks have sensors that give output 0 when they are not covered by water, but output 1 when covered. In the header tank, sensor 1 is at the top, to detect when the tank is full (=1). In the storage tank, sensor 2 is near the bottom to detect when the tank is (nearly) empty (=0). What is the logic required? It would be an interesting practical project to build and operate a small-scale version of this system. But read the next section before you begin. A solution is given on p.40.

These have been fairly simple examples of logical design. But complicated ones, such as the control system of a washing machine or a computer printer, may all be tackled in the same way. We write down what we want to happen, convert this to truth tables and then to logic hardware. We need to keep a pretty clear head when doing this, but the few essential logical processes are the same no matter how complex the application.

PRACTICAL DESIGN PROBLEMS

We tend to think that logic gates act instantaneously but, in practice, all gates take time to respond to a change of input. The time is very short by our standards. For example, a ttl gate takes about 10ns (1,000,000,000 nanosecond = 1 second). But the time is not short

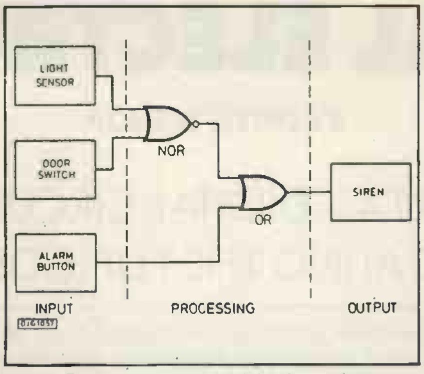


Fig.7 *Security system with alarm button.*

when reckoned by logic standards. We may need to take it into account when designing logic circuits. For example, in Fig.7 the result of a change in the input from the door switch has to pass through two gates before it reaches the siren, but the result of a change in the input from the alarm button has to pass through one. If we open the door and press the button at exactly the same time, there is a race through the system. The effect of pressing the button wins by 10ns! This is of no importance at all in this system but it is a good idea to have thought about it at the design stage and to have checked that it really *is* nothing to worry about. In a more complicated security system it could happen that a race results in the siren being triggered to sound when it should stay silent. There is more on these lines in the section below on counters.

Another point to consider when turning designs into hardware is economy in the number of ics required. In Fig.7 for example, we need a nor gate and an or gate. It is uneconomical to use a 7402 for the nor and a 7432 for the or, so wasting three gates in each ic. With a little logical juggling you can set up the equivalent circuit using only nor (Fig.8), in a single 7402 ic. The or is replaced by a nor followed by not (so this gives not-not-or, equivalent to or). Similarly, the circuit of Fig.9 can be realised with a single 7402. As before, the not gate is replaced by a nor gate with its inputs connected.

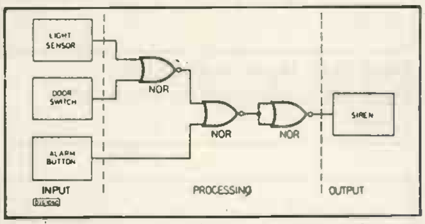


Fig.8 *The system of Fig. 7 using only NOR gates.*

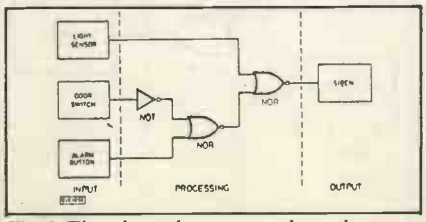


Fig.9 *The alarm button works only at night.*

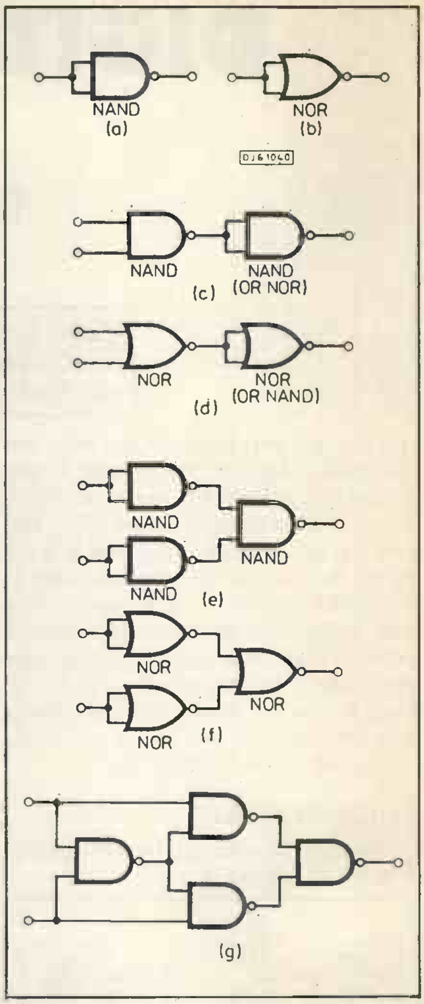


Fig.10 *Making up gates from NAND and NOR. (a) (b) = NOT; (c) = AND; (d) = NOR; (e) = OR; (f) = AND; (g) = exclusive OR.*

When you are designing larger logical systems, count how many gates of each sort you need and try to reduce the number of ics to the minimum. This not only saves cost and current, but board space too. Usually it is better to try to work mainly nand and nor gates, as they can be pressed into service to substitute for other kinds of gate of which you may need only one or two (Fig.10). The pumping circuit of Fig.11, for example is better realised in nand than in and, for this allows the not gate to be obtained from a nand gate (Fig.12).

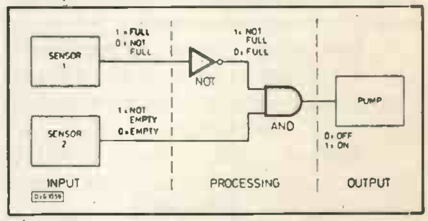


Fig.11 *Water pumping logic.*

No matter how ingenious the design it seems to be an invariable law of logic circuitry that, when the design is finished, there is always just one gate that can not be catered for. An extra ic has to be included just for the sake of one of its

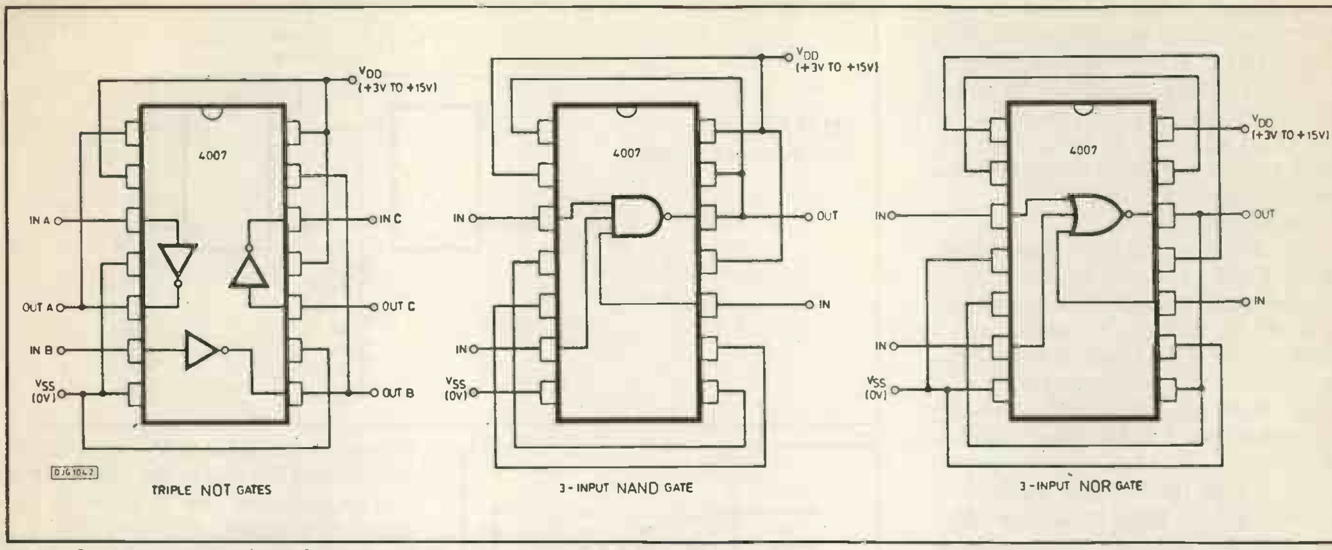


Fig.12 *Some logic gates built from the 4007.*

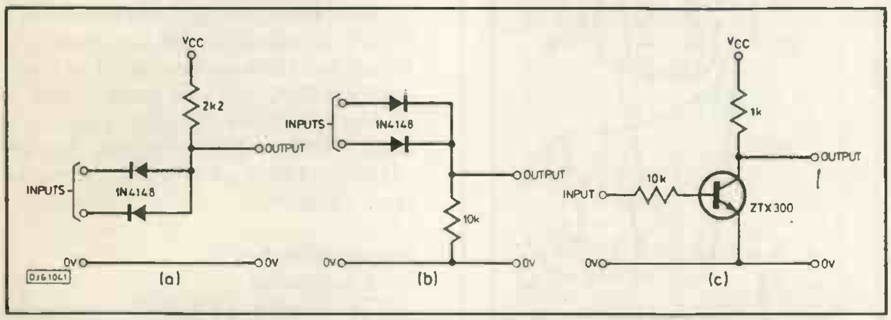


Fig.13 *Mickey-Mouse logic. (a) 2-input AND gate; (b) 2-input OR gate; NOT gate.*

gates. Sometimes you can get round this by building your own gate from diodes or transistors. This approach is known as Mickey-Mouse Logic or M^{2}L for short. Fig.13 shows a few examples of M^{2}L that you may find useful. Try these out on a breadboard to see how they work. But beware! M^{2}L may sometimes not work well, especially at high speed. Check it!

Another way of providing the 'odd' gate is to use the cmos 4007 ic, as described in the next section.

DO-IT-YOURSELF LOGIC

The 4007 is technically known as a 'complementary pair plus inverter'. It can be made to substitute for many kinds of gate. As usual, we treat the ic as a black box and simply show you how to make the necessary connections (Fig.12). There are external connections to be made, as shown in the diagrams. The 3-input gates can be used as 2-input gates if you wire any two of the inputs together. The 4007 has several other applications as a diy gate – refer to the manufacturer's data sheets.

SEQUENTIAL LOGIC

In most of the logic circuits that we have looked at, there are a number of input terminals and one output terminal (though there can be more). The state of the output depends on the states of the inputs at *that moment*. One circuit that we looked at in Part 2, is not quite like that. This is the RS bistable (or flip-flop). The state of its output (or outputs) depends on which of its two inputs was most recently made low. In other words, its *present* output state depends on what the input states were *some time ago*. Also, when the flip-flop is set, making the set input low has no effect; it stays set. But making the reset input low causes the flip-flop to change state; it resets. Logic circuits of this type follow a *sequence*. They flip and then flop! What happened in the past determines what happens now. This is what is meant by sequential logic.

Another sequential logic circuit is the D-type flip-flop. Find out what it does, using the 7474 (or 74LS74) ic.

Investigation 1
the D-type flip-flop

Fig. 14 shows the circuit and Fig. 15 shows how to set it up on a breadboard.

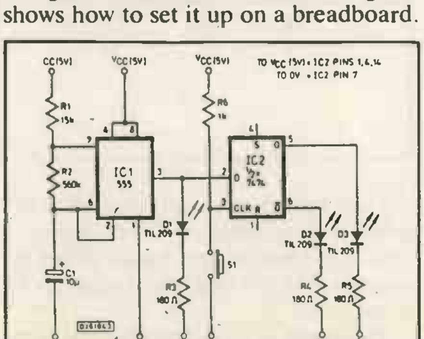


Fig.14 *Investigating the action of a D-type flip-flop.*

If you have built Module 2 (indicator leds), you can use it instead of the leds in this circuit and others. We use our astable to send data to the D input of the flip-flop. This is based on the 555 ic (see last month's article). The astable is running slowly (about 0.25Hz) to give you time to see what happens. A led (D1) shows the state of the astable's output. Each flip-flop (there are two in the 7474, but we are using only one of them) has a clock input which is controlled by a push-button. With the button pressed the clock input is low: when it is released the clock input is high. The flip-flop has two outputs; leds are wired to these to show the output states.

Connect the battery and try to answer these questions about the D-type flip-flop:

1) Watch the leds. Try pressing S1 at various times. At what stage do the out-

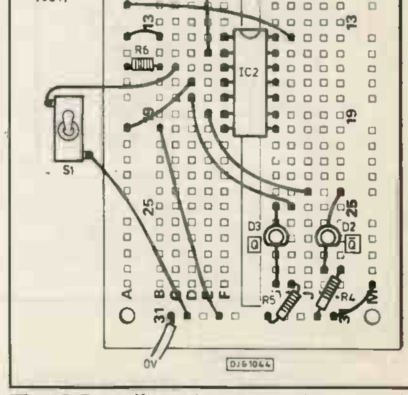


Fig.15 *Breadboard version of circuit of Fig. 14. Note that top section down to line 13 is the same in Figs.17,19,21,22,25.*

puts change? When the clock is low? When the clock is high? When the clock changes state? If so, what clock change?

2) Try pressing or releasing S1 during several astable cycles. Try to make output Q go high. Try to make it go low. What can you say about D and Q? What can you say about D and $\bar{Q}$?

Answers are on p.40.

The flip-flop has two other inputs, RESET (pin 1) and SET (pin 3). These are connected to high. Remove the lead between V_{cc} and pin 1; connect pin 1 briefly to 0V. What happens to Q? Does the state of the clock affect what happens? Make pin 1 high again. Now try connecting pin 3 to 0V. What happens now?

The D-type flip-flop has applications for storing data. It can be made to store the data that is present at a particular instant, the moment when the clock output rises from low to high. The flip-flop has another application, as the following investigation shows:

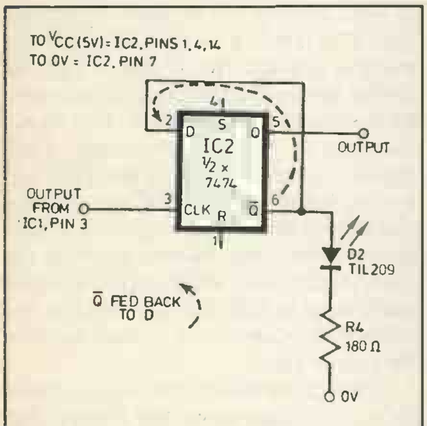


Fig.16 *Circuit for investigation 2 – stage 1.*

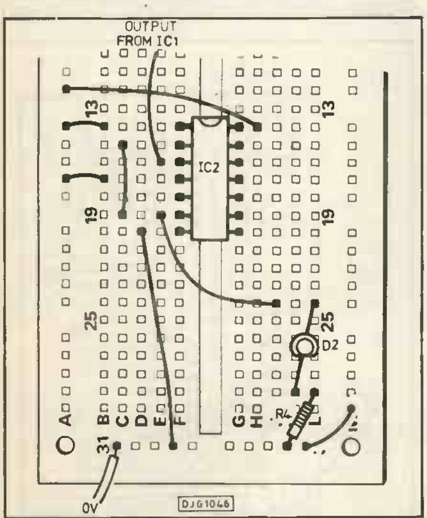
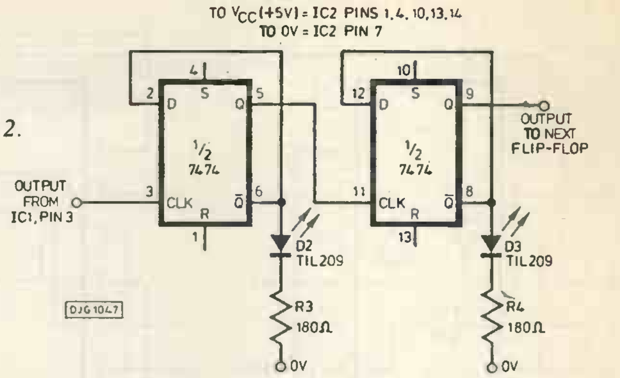


Fig.17 *Breadboard version of Fig 16. Note that input from IC1 goes to pin 3 of IC2.*

Investigation 2
connected flip-flops

The circuit (Fig. 16) shows a flip-flop with its $\bar{Q}$ output fed back to the D input. In this circuit the flip-flop is clocked regularly by the output from an astable. At each rising clock edge, the NOT (or inverse) of the present data input becomes the next data input. Set up the circuit (Fig.17) to see what this means in practice. On one rising edge the led (D2) comes on. On the next rising edge it goes off. The led goes on and off at *half* the rate of the clock's led (D1).

Fig.18 *Circuit for investigation 2 – stage 2.*



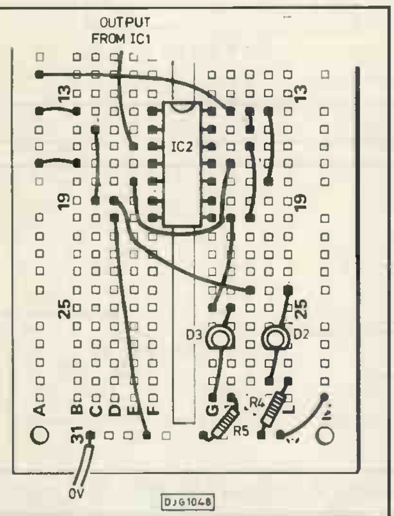


Fig.19 *Breadboard version of circuit of Fig. 18.*

Now connect a second flip-flop (in the same ic) to the first one, so that the Q output of the first one goes to the clock input of the second one (Fig.18,19). In both flip-flops the $\bar{Q}$ output is connected to the D input. Watch what happens now. Write down what happens to the leds, beginning from when they are all off. Write '0' for 'off' and '1' for on.

D3	D2	D1
0	0	0
...	...	...
...	...	...
...	...	etc

Does the sequence repeat itself? How many stages does it have before it repeats? What do you notice about the sequence of '0's and '1's? (Answers on p.40)

There are two ways of looking at the behaviour of this circuit:

1) The output of the first flip-flop changes state at half the clock rate. The output of the second flip-flop changes state at half the rate of the first flip-flop – at a quarter the rate of the clock. The circuit is a *frequency divider.* This can have uses for producing different frequencies in audio or timing circuits.

2) The circuit counts input pulses. As it is only a 3-stage circuit it counts only from 0 to 7, before repeating. If you have another 7474, you can connect this to give a chain of five flip-flops. This counts from 00000 to 11111 (decimal 31). By extending the chain you can count even large numbers.

Investigation 3
the J-K flip-flop

This flip-flop (Fig.20,21) is named after its two inputs, called J and K. Like the D-type flip-flop it has Q and $\bar{Q}$ outputs, $\bar{Q}$ being the inverse of the Q. To make things easier we will look at only the Q output.

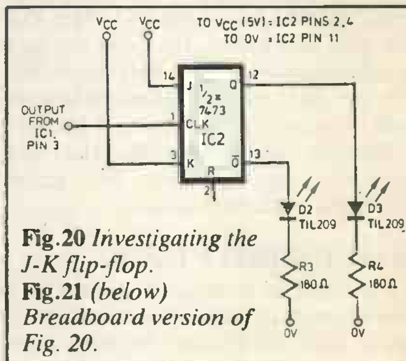
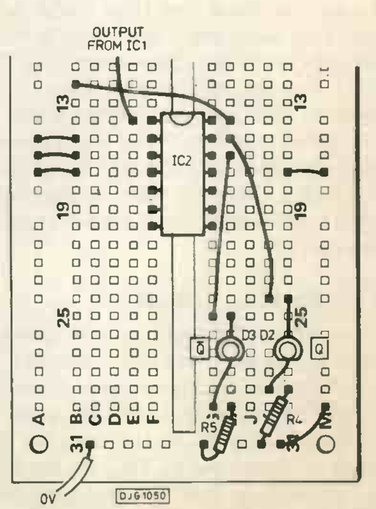


Fig.20 *Investigating the J-K flip-flop.*
Fig.21 *(below) Breadboard version of Fig. 20.*



The diagram shows both J and K connected to high. Connect the battery and watch what happens. When does the Q output change state?

Wait until the output is low, then transfer the J input wire to the 0V line. Now J is low and K is high. How does the output behave?

Now make J high and K low. What happens now?

Finally, make both J and K low and observe what happens to the output.

The output of a J-K flip-flop can be 'steered' by applying suitable inputs to J and K. With J and K both high, so that the output changes at half the clock rate, J-K flip-flops can be wired in a frequency-dividing or counting chain in the same way as the D-type flip-flop.

COUNTERS

It is useful to be able to make a counter (or frequency-divider) from a chain of D-type of J-K flip-flops. But, if many counting stages are needed, it is more convenient to buy the counting circuit ready-connected in a single ic. One example of this is the 7493 counter (Fig.22). The counter is in two sections. One section (A) is a single flip-flop, the other is a chain of three flip-flops (B, C and D). This allows you to use the ic as a 'divide by 2' counter and an independent 'divide by eight' counter. Usually we chain the two together to give a 'divide by 16' counter, as in the diagram.

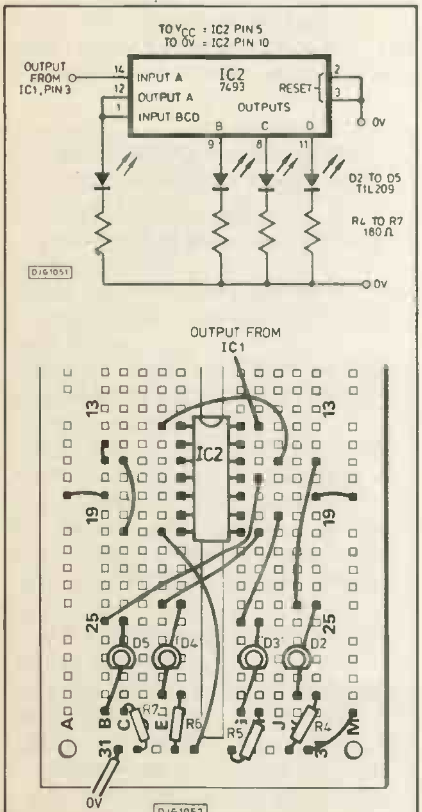


Fig.22 (top) Demonstrating the 7493 counter chip.
Fig.23 *(bottom) Breadboard version of circuit of Fig 22.*

Set up the circuit (Fig.23) to see how it works. Record the state of the lamps starting from when they are all off. Write '0' for 'off' and '1' for 'on':

D5	D4	D3	D2
0	0	0	0
.	.	.	.
.	.	.	.
etc			

There are 16 stages before it repeats. These represent the binary numbers 0000 (decimal 0) to 1111 (decimal 15).

NUMBER SYSTEMS

While we are on the subject of binary numbers we will look at the various ways of representing numbers in logic circuits. The simplest method is in binary form, as above. This is the simplest because we are using binary logic in which inputs and outputs are either high or low. Similarly, in the binary number system, the digits are either 0 or 1. It is straightforward to represent the digit '0' by a low input or output, and the digit '1' by a high input or output.

Binary is easy enough if our numbers have only a few digits, but becomes more difficult to cope with if there are many digits. Unfortunately, the larger binary numbers have more digits that their decimal equivalents. The number 54331, for example, is 1101010000111011. Writing out such long strings of digits is tedious and liable to error. Because of this we prefer to write our binary numbers in *hexadecimal* form. Actually hexadecimal numbers are a number system in their own right, but we can think of them as a short-hand way of writing binary numbers.

The first 16 valves in the three systems are written like this:

Binary	Decimal	Hexadecimal
0	0	0
1	1	1
10	2	2
11	3	3
100	4	4
101	5	5
110	6	6
111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

For values from 0 to 9, the hexadecimal system uses the same symbols as the decimal system. After that it uses the letters A to F for the equivalents of decimal 11 to 15. It would have been possible to invent a half-dozen entirely new symbols for the purpose, but it is easier for everyone if we borrow a few letters from the alphabet instead.

Converting a binary number into hexadecimal is done like this, using the example from above:

1. Write down the binary number with its digits in groups of four:
   1101 0100 0011 1011
2. Look in the table above to find the hexadecimal equivalent of each group:
   D 4 3 B
3. The hexadecimal equivalent of 1101010000111011 is D43B.

Converting hexadecimal into binary is the reverse of the above:

1. Write down the hexadecimal number:
   A 7 F 0
2. Under each digit write the binary equivalent, from the table above:
   1010 0111 1111 0000
3. The binary equivalent of A7F0 is 1010011111110000.

THE LOGIC OF DECIMALS

Humans find it tedious to work in binary and confusing to work in hexadecimal (just think of having to learn your 'D-times table' at school!) We are brought up on the decimal system and have a convenient number of fingers (including thumbs) to help us in the early stages.

Computers and calculators work in binary; highs and lows are all they understand. This means that all the decimal values that you key into a computer must be converted into binary in the computer. They are stored in the computer's memory in this form. If you key in '57' for example, it is stored as '00111001'. In the appropriate block of memory, 8 flip-flops in a byte of memory are set (=1) or reset (=0) to store these digits.

The computer performs its calculations in binary arithmetic, working on the stored values. The answer is stored in binary. But the computer normally tells you the answer by displaying it on the screen in decimal. It uses in-built routines to do the conversion.

A decimal value such as '57' is held in the computer as its binary equivalent. In cash registers, voltmeters, petrol pumps and other devices that have a digital display, it may be more convenient to convert the decimal value into a different system. Instead of converting the value as a *whole* into binary, we convert its digits *separately*.

In this system we use four bits for each digit. The value of '57' becomes:

The tens digit is '5', which is converted to 0101

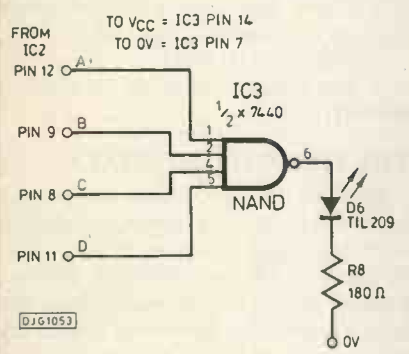
The units digit is '7', which is converted to 0111

The conversion for '57' is 01010111

This is not a true binary number, for the actual value of 01010111 is 87, not 57. It can not be used in calculations. It is a *code*, representing '57'. Decimal values expressed in this particular way are referred to as *binary coded decimal*, or bcd for short. Special ics have been developed for handling bcd codes. We often use these for driving digital displays.

COUNTING

When a series of pulses is fed to the 7493 counter (Fig.22) its outputs run through all the 4-bit binary values, from 0000 to 1111. In Fig.24 we see how to detect when the counter output is 1111. At that stage all outputs to the 4-input NAND gate are high, so its output goes low. Set this up on a breadboard, as in Fig.25. When you connect the battery, the led (D6) is on for most of the time but flashes off when the counter reaches 1111.



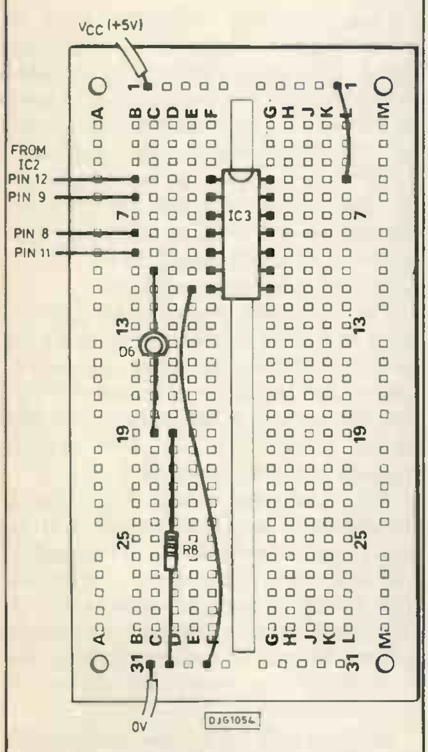


Fig.24 *(top) Detecting the count of '1111'*
Fig.25 *(bottom) Breadboard layout for Fig. 24.*

We can make D6 flash at other stages if we feed the counter output to a suitable detector circuit. For example, to make D6 flash every time the counter reaches 9 (binary 1001), we need to detect when outputs A and D are high but outputs B and C are low. Fig.26 shows the circuit. The B and C outputs are fed to NOT gates to invert them.

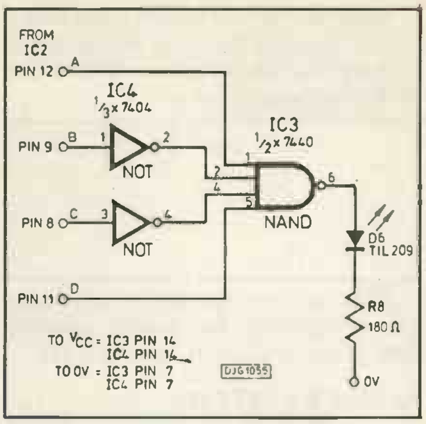


Fig.26 *Detecting the count of '1001'.*

When the count is 9, outputs A and D are high and the outputs from the NOT gates are high. All inputs to the NAND gate are high, its output goes low and D6 flashes off. Try this using a 7404 to provide the inverters. Or you can use NAND from a 7400, as in Fig.10a.

The low-going output from the detector circuit can be used to reset the counter. When either one of the reset inputs of this ic is made low, the counter immediately resets to 0000. Try this on the bread-board. Instead of wiring pin 2 of IC2 to 0V, wire it to the output (pin 6) of IC3. We now have a counter that counts up to 8 but, is reset as soon as it tries to go to 9. Watch the leds run from 0000 to 0100, then reset to 0000. Alter the detector circuit to make the counter reset at 6 (0110) – ie, it counts up to 5, then resets. A counter that does this is called a *modulo-5 counter*. In general, a counter that runs from 0 to *n* is called a *modulo-n counter*.

Modulo-*n* counters have many application where you don't want to count up to the standard 8, 10, 12 or 16 that the ready-made ics offer. They are also useful as *frequency dividers*. If you need to provide a frequency that is a fifth of a given frequency, use a modulo-5 counter. A good example is in building a digital clock in which you have a basic frequency of 1Hz for timing seconds. For timing minutes you need a frequency 1/60th of this. Feed the 1Hz frequency to a modulo-10 counter and feed the output of this to a modulo-6 counter. The output from this has a frequency of 1 per minute.

RIPPLES

In Fig.18 the second flip-flop changes state when the input from the first flip-flop changes. In a longer counting chain the second flip-flop causes the third flip-flop to change and so on down the chain. Earlier we mentioned that logical devices do not change state instantly. There is a delay of a few nanoseconds between a change of input and a change of output. The flip-flops in a chain change state *one at a time*. The effect of a change at the first flip-flop *ripples* along the counter. For example, if a 4-bit counter is at 1111, the next count takes it to 0000, one bit at a time:

Before change	1111	The effect ripples from right to left, from least significant to most significant digits.
	1110	
	1100	
	1000	
Change completed	0000	

This all happens so quickly that, if you watch leds connected to the counter, you see only an apparently instant change from 1111 to 0000. But if there was a detector circuit to detect, say, a count of 12 (1100) it could easily detect that the counter output actually went through 1100 before it got to 0000. This could lead to false triggering of some other part of the circuit.

To take another example, an 8-bit counter changing from, say, 159 to 160 goes through these stages:

Start 159	10011111		
	10011110	158	
	10011100	156	)Transient
	10011000	152	) Output
	10010000	144	) Stages
	10000000	128	)
Change to 160	10100000		

A counter that behaves in this way is known as a *ripple counter*. It is also known as an *asynchronous counter*, because the outputs do not all change at once. When using counters of this type we have to beware of outputs that appear briefly and which may affect detector circuits. In modulo-*n* counters there is no problem; the transient stages all give values less than the start and finish values. But, in a system in which several different operations have to be triggered at

ANSWERS TO QUESTIONS
Don't look until you need to!

Security system: (Figs.7 and 9)
Pumping system: (Fig.11)
Design problems: (Fig.8)
Investigation 1:
1) The outputs change when the clock input changes from low to high.
2) When the clock input goes high, Q becomes the same as D. $\bar{Q}$ becomes the inverse of D.
When $\overline{RESET}$ is made low, Q goes low, $\bar{Q}$ goes high.
When $\overline{SET}$ is made low, Q goes high, $\bar{Q}$ goes low.
Investigation 2: The sequence repeats itself after 8 stages. The eight stages are the binary numbers 000, 001, 010, 011, 101 and 111 (0 to 7 in decimal).
Investigation 3: With J and K high, Q changes state every time the clock input goes low.
With J low and K high, Q goes low when the clock next goes low, and then stays low.
With J high and K low, Q goes high when the clock next goes low, and then stays low.
With J and K both low, Q remains unchanged indefinitely.

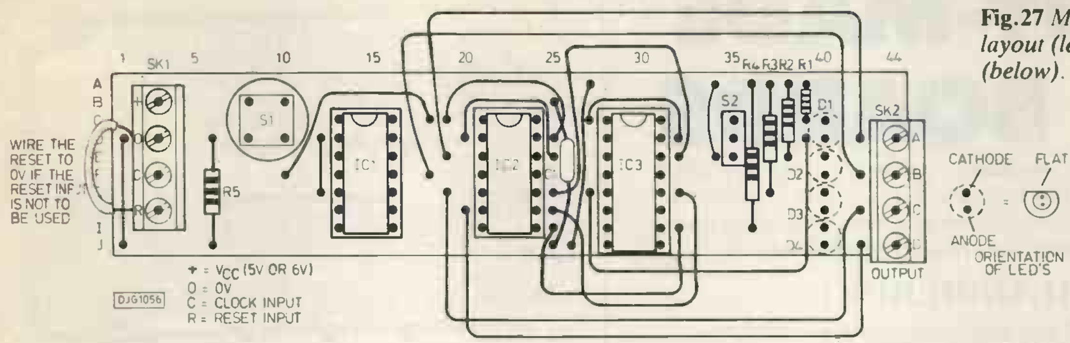
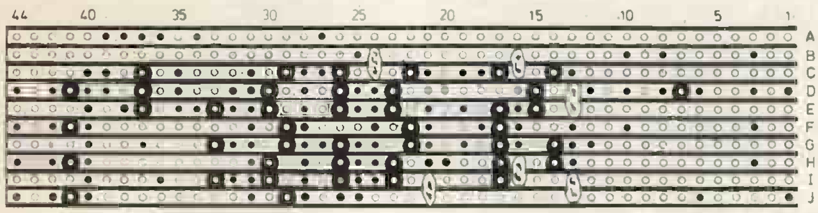


Fig.27 *Module 6 component layout (left) and track view (below).*



given counts, we may find that some operations are triggered at the wrong times. The solution is to use a *synchronous counter*. In this type, all the flip-flops are clocked simultaneously and all outputs change at exactly the same instant.

MODULE OF THE MONTH
6. Four-bit counter (Fig.27)

This uses the 74LS393 4-bit ripple-counter, with a reset button and four leds to indicate output. There are two counters in this ic, both similar to the counter in the 7493. We are running them in parallel so that one provides the led output and the other the output to the terminal sockets. The counter operates when the input changes from high to low.

The counter is reset either by pressing the button or by a high pulse to the RESETterminal. If you are not using the RESETterminal, wire it to the OVterminal. The leds are driven through buffers in a 74LS367. The leds are enabled when the switch is down. They are disabled when the switch is up. This module requires 80mA.

Parts required
R1-R4 180 ohm, 0.25W, carbon
R5 1k, 0.25W, carbon
C1 100n polyester
D1-D4TIL209 or similar leds
IC1 74LS02 quadruple 2-input NOR
IC2 74LS393 dual 4-bit counter
IC3 74LS367 hex bus driver
S1 push-to-make p.c.b. mounting push-button
S2 p.c.b. switch spdt
SK1, SK2 pc terminal 4-way (2 off)
14-pin dil sockets (2 off)
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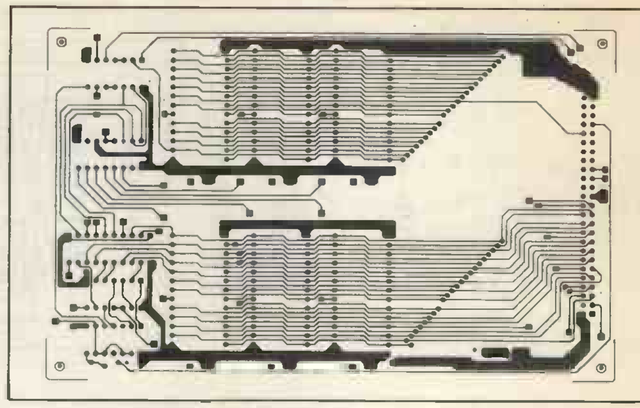

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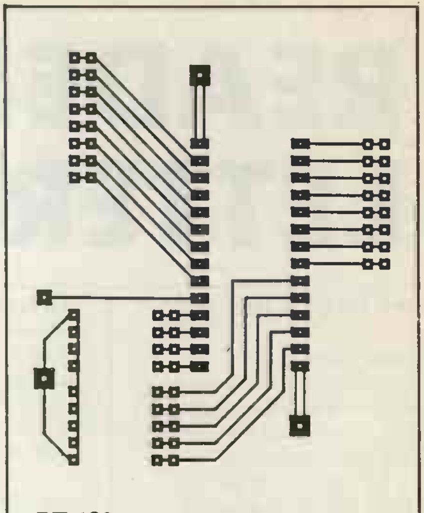
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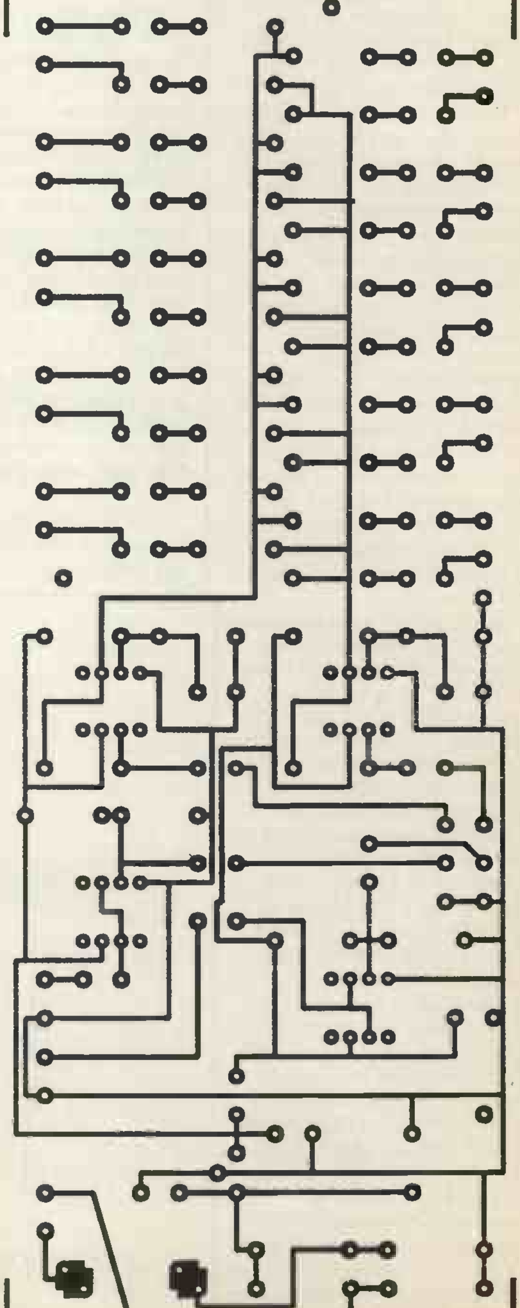

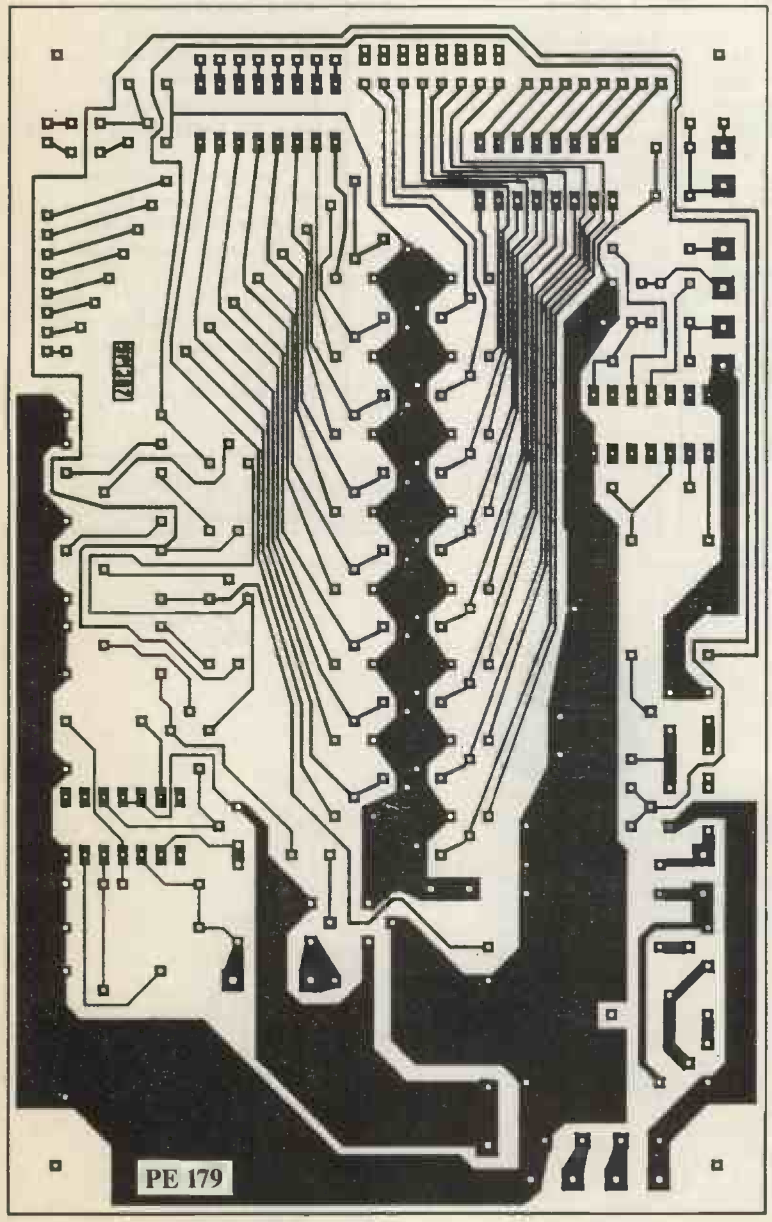
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READERS' LETTERS

PIPE DREAM HOUSE

Dear Editor,

My interest in the fascinating hobby of electronics goes back to the war years, and came into being from the fact that I was a wireless operator/airgunner. During this time I acquired enough knowledge to enable me to follow a circuit diagram, though I never became anything of a 'boffin' as regards radio. Come to think of it, the only 'bullets' I have fired since those far off days have been metaphorical, so to speak.

Having grown up in the era of the cinema, I was smitten by the wonders of the cinema organs featured then, and so set about constructing simple musical instruments at home in order to copy some of the sounds I enjoyed. These were monophonic to start with, but eventually, I constructed a 2-manual full compass polyphonic electronic organ of the free-phase variety, and which still functions today.

Having been swept away on the tide of enthusiasm, 1963 rates as a milestone with this hobby, for it was then that I purchased one of the few Dutch cinema organs that were imported into this country.

At this point I must emphasise that I live in a modest terraced home, and the only way I could accomplish my goal of accomodating this 'giant' was to install an organ chamber in the roof to take all the pipes, percussions and effects. The 3-manual console moved into the ground floor lounge and took up residence where I had made room for it by knocking out the chimney stack. The blower at that time went into a 'pit' which I dug below the floor to a depth of six feet. A compromise had to be reached here, whereupon I placed ribbon microphones in the organ chamber to transmit the sounds down through a battery of hidden speakers, set above and below a large 'picture' window in a sort of procenium arch.

Over the years I have augmented the sounds of the pipe organ with such additions as a piano accordion, set in chamber and operated by electromechanical 'fingers' when played from the organ manuals. The same setup exists with a Cassio keyboard (remotely controlled), and my former homemade electronic organ is also set in the roof and wired in through the relay system of the pipe organ.

One sacrifice had to be made in regard to the bass pipes of the organ. Lack of space, plus consideration for the neighbours, decreed that I produce the bass notes of the 16-foot pitch by electronic means..

Consequently, although my oscillators with their ECC82 valves are still giving good service, I recently purchased a couple of master oscillator chips which produce a whole octave in one go, but I am in the dark when it comes to some modern form of switching the notes. Asking around component suppliers, I find that most are discontinuing their organ spares as apparently people are finding it cheaper to buy commercial instruments. In the past I have used solenoids but have heard that modern semiconductors are capable of doing a similar job and I want to know more about them.

E.R. Hart, Morehall, Kent.

I really admire your ingenuity and tenacity. Jim Naylor is impressed as well!

Sadly, it is true that commercial instruments are ousting equivalent diy components, but I have heard of people who buy cheap keyboard instruments, strip out most of the electronics and substitute their own much improved circuitry. We both know that a true enthusiast can never be deterred!

There are several ways of gating the output notes. If the signal is a squarewave of suitable amplitude, any of a multitude of ttl and cmos gates can be used, controlling them by means of the keyboard switches, switching between high and low logic levels as appropriate. For analogue signals one of the most universally used chips is the 4066. It has four gates each of which can be controlled by keyboard-switched voltages. The gates will pass or inhibit analogue voltages according to the logic level on the control pins.

Many component suppliers should be willing to sell you data sheets on this, and several other analogue or digital gates. Some of the latter have more than four gates to a chip.

You might also care to join the Electronic Organ Constructors Society, they can be contacted through The Hon Sec, E.O.C.S., The Mill House, Mill Lane, Wheaton Aston, Stafford, ST19 9NL.

I wish you every success with your reorganisation.

Ed

SEEN IT ON THE GRAPEVINE

Dear Editor,

I believe that an article was once published in which paw-paw trees and other plants were shown to act as tv antennae. Old flourescent light tubes have also been used as tv aerials. Is there any explanation for that?

A.S. Osibo, Ibadan, Nigeria.

You have me puzzled. I have no recollection of any article on the subject, and no idea how a paw-paw, or other plant, might be used as an antenna, except as the support for one. Interestingly, my horticultural encyclopaedia quotes one plant that has the name of Antennaria and apparently it propagates well, but I suspect the reference is more down to earth than aetherial!

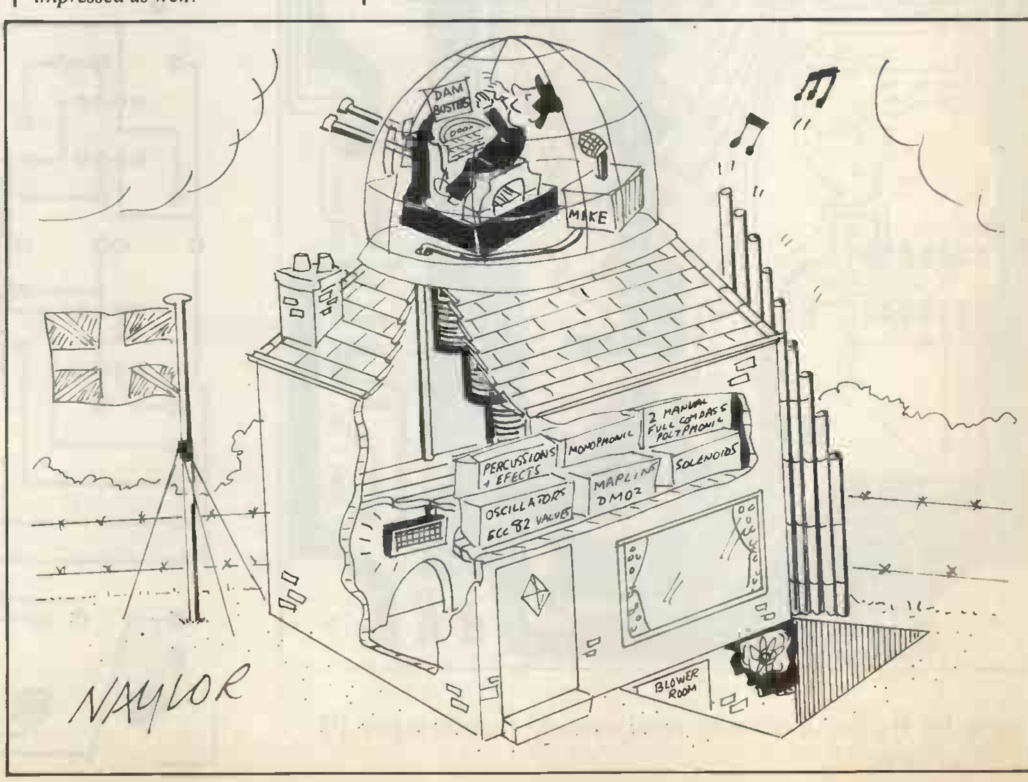
It might just be, though, that you were the unwitting victim of an April 1st practical joke – we have some quaint traditions in Britain. Remember Zola McMalcolm's article on bio-chromatic electronics in PE April 88?

Fluorescent tubes are another matter – they glow when unconnected if subjected to powerful radio transmissions in their vicinity – try holding one near a cb radio while transmitting. I have not heard of them being used as true aerials, though.

Perhaps other readers might tell us more about these oddities.

Ed.

1989 is PE's 25th anniversary year.
Have you a PE-related anecdote to tell?



OUR REGULAR LOOK AT ASTRONOMY

SPACEWATCH

BY PATRICK MORE CBE

TECHNOSAURUS REX?

In the USA, seers are being stymied by cash cutbacks; and we may discover what became of dinosaurs sooner, and more precisely, than we would like.

Now that Jupiter is well placed, many amateur observers will be looking at it, and studying its changing surface as well as the phenomena of the four Galilean satellites. By now the Galileo probe should have been on its way there; but with the cutbacks in the US space programme, the launch date is now November 1989, and because the launcher will be less powerful than originally planned the orbit will be very convoluted. Two passes of the Earth and one of Venus will be made before Galileo finally reaches Jupiter in late 1995.

Observatories as well as space programmes are being hit by American financial cutbacks, and several important projects have been postponed indefinitely. One of these is the Advanced Telescope Programme, destined to oversee the next generation of giant telescopes. Astronomers will sigh wistfully as they see their research being held up while vast sums of money are poured into military projects aimed only at destruction ...

However, our own William Herschel Telescope on La Palma has been thoroughly tested, and Dr Paul Murdin, who was in charge of it at the outset, has told me that it is even better than anyone had dared to hope. It is widely regarded as the world's best telescope at the present moment. Meanwhile, the Russians are building what will be the largest radio telescope devoted to millimetre-wavelength observations; the disc will be 70 metres in diameter, and will be set up in Soviet Uzbekistan. When completed, it will be linked with telescopes of the

The Sky This Month

During November, most of the bright planets are on view at one time or another. Venus is still prominent in the eastern sky before sunrise; the phase increases from 80 per cent at the start of the month to 86 per cent at the end, so that telescopes will show almost nothing on its bright, gibbous disc. The apparent diameter is about 13 seconds of arc – remember that Venus is at its closest to us when at inferior conjunction, when the apparent diameter attains over 56 seconds of arc, but as the dark side is then facing us we do not benefit! The other inner planet, Mercury, is also technically a morning object, but is not likely to be seen after the first week in November, as it is drawing in toward inferior conjunction.

Mars, still in Pisces, declines from magnitude –1.7 to –0.9 so that even at the end of November it is brighter than any star except Sirius. The apparent diameter has dropped to 14 seconds of arc, and at the end of the month the phase is no more than 91 per cent, so that telescopes show the planet to be decidely gibbous.

Saturn is still in the south-west after dusk, but very low. Jupiter, on the other hand, comes to opposition on November 23 at a distance of 603,000,000 kilometres; it is unmistakable, moving slowly in Taurus between the Hyades and the Pleiades.

The moon is new on November 9, and full on the 23rd. There are no solar or lunar eclipses this month. Neither are any bright comets expected (though with comets, one never knows). There are, however, two meteor showers. The Taurids are active throughout the month, but the ZHR (Zenithal Hourly Rate) is seldom more than eight; on the other hand the Taurids tend to be swift and bright, with fine trains. At 8 hours GMT on November 17 we are due for the maximum of the Leonids, which are the most erratic of all annual showers; generally they are very sparse, but occasionally they can produce veritable 'storms', the last of which was seen in 1966. Frankly, any major Leonid activity this year is unlikely, and we do not expect another 'storm' before 1999, but it may be worth keeping a watch on the night of November 16-17 just in case we are wrong.

Orion bow rises at a respectable hour, and will continue to dominate the evening sky right through until the spring. It contains spectacular objects of all kinds, including two brilliant stars, the red variable Betelgeux and the pure white Rigel; Rigel is at least 60,000 times more luminous than the Sun, but it is around 900 light-years away, so that we now see it as it used to be at the time of William the Conqueror.

Look also for the great gaseous nebula Messier 42, below the three stars of the Hunter's Belt; this is one of the regions where fresh stars are born – a true stellar nursery. In line with the Belt is the red Aldebaran, from which extends the star-cluster of the Hyades, and beyond the Hyades we come to the Pleiades or Seven Sisters, the most famous open cluster in the sky. People with average eyesight can see at least seven Sisters without optical aid; the record is said to be nineteen.

Ursa Major, the Great Bear, is low in the north, which means that the W of Cassiopeia is almost overhead; the Bear and Cassiopeia are on opposite sides of the north celestial pole, and at about the same distance from it. Capella in Auriga, the Charioteer, is high up, and is easy to identify because of its brightness; it is yellow, like the Sun, but is much more luminous, and is actually a very close double. Much of the southern aspect is occupied by Cetus, the Whale, which has no brilliant stars, but is redeemed by the presence of the prototype long-period variable Mira, which however is not yet at its best. Finally, use binoculars to sweep the Milky Way, which stretches right across the sky. It is tempting to conclude that the stars in the Milky Way are in danger of colliding with each other, but less easy to realise that we are seeing nothing more than a line of sight effect; we are looking along the main plane of our flattened Galaxy, and seeing many stars in almost the same direction.

same type now operating in Japan and in Spain. It will also eventually link with antennae placed in orbit round the Earth.

DOOMWATCH

Recently we have heard even more the theory that the dinosaurs were wiped out by the results of a meteoric impact some 65,000,000 years ago. One of the chief protagonists of this theory, Dr Luis W. Alvarez, died last August; he was noted for his brilliant physical research (he won a Nobel Prize) and also for his acid comments about scientists who questioned his theories – "ignorant and incompetent" and "little better than stamp-collectors" were two of his strictures. Alvarez based his ideas on the existence of a relatively large quantity of iridium in sedimentary rocks corresponding to an age of 65 million years. There has since been a suggestion that gigantic fires raged over many parts of the world at that time. On the other hand, it has also been suggested that the dinosaurs died out not abruptly, but gradually over a period of from 10,000 to 100,000 years, which would remove the need for a meteoritic disaster. Alvarez was challenged by Dr Beverly Halstead, of Reading University, who said: "The dinosaurs were already dying out 65,000,000 years ago. Perhaps they died because they had foreknowledge of the comet collision and didn't want to spoil your theory!"

Whether or not the dinosaurs perished by a comet or meteorite impact remains uncertain. However, Dr Victor Clube, following up his recent research article in *Astronomy Now*, has claimed that a collision between the Earth and a cluster of comets is overdue, and may well happen within the next hundred years. If so, it will be interesting to see whether our modern technology is able to cope with the crisis better than the dinosaurs did. PE

SUBMARINE CABLES

PART THREE BY MIKE SANDERS

MONARCHAEOLOGY

Hi-tech aids facilitate cable laying, but to recover and repair a buried cable it is better to have a dog to fetch it.

Presently the ships operating from the UK are cable ships (CS) Monarch built in 1975, weighing 3875 tons, CS Iris also 3874 tons built in 1976 and CS Alert 6083 tons built in 1961. The Monarch and Iris are used mainly for repair around the coast though they can be used in deep water as well.

The Alert is used for deep water repair and cable laying. All three ships operate from Southampton and sometimes work for foreign administrations. It is important for a repair ship not only to carry stocks of different types of cable for repair purposes, but also to carry large stocks of water and food for many months at sea.

Before a ship starts laying the deep water sections, the shore ends are laid to avoid keeping the ship waiting. When the ship starts laying the deep water sections and exhausts its stock of cable, it attaches a buoy to the end of the cable and returns to harbour for a new stock of cable.

Since the Monarch and Iris are similar they will be described here. Each has ten cable tanks capable of accepting preloaded pans of cable weighing 70 tonnes each. Each ship carries a complement of about 60 officers and men and is powered by two 2600 bhp engines.

The ships have helicopter landing pads so that men and materials can be flown out at short notice. They also carry all the latest navigation aids: Decca, Loran, radar, sonar, gyro compasses. Use is also made of satellite navigation.

There were two previous ships called Iris. They were around 2000 tons and the second Iris was involved in laying the Pipeline Under the Ocean (PLUTO). This pipeline supplied oil for the Normandy landings of World War II.

There were four previous ships called Monarch. The first was only 512 tons with a 130hp steam engine. It was a wooden paddle ship and laid the Dutch cables in 1853. The second Monarch was of double the tonnage but still used a steam engine. It hit a mine off Folkestone in 1915.

The third Monarch was shelled by an American destroyer by accident in 1944. It was repaired and put to sea, only to be mined off Southwold. The fourth Monarch was the largest cable ship in the world at 8055 tons and after 25 years service was sold to Cable and Wireless in 1970. It was renamed Sentinel.

Cable ship Monarch loading submersible trencher "Sea-Dog". By kind permission of British Telecom.

FAULT FINDING

As mentioned in an earlier section it is possible to locate a fault from a terminal station. However, this ties it down to an approximate area between two repeaters and there could be several miles between repeaters. When the ship arrives at the approximate location, it is necessary to conduct further tests to pinpoint the fault more accurately.

Two electrodes are towed on the stern side of the ship and the potential difference of a low frequency alternating current is measured. When the ship has passed the damaged section the meter deflection dies away. This is called electroding.

Having located the exact position of the fault it is then necessary to grapple for the cable. Here is where the strength of the cable comes in; it must not only be light and flexible, it must also be strong. The ship grapples for it by making passes across the cable with grappling tools.

A dynamometer is attached to the grappling rope and as soon as the cable is hooked the strain gauge of the dynamometer climbs.

Sometimes a cable can be mended merely by repairing the outer insulations but in most cases the cable is sufficiently damaged to warrant jointing in a new section.

Occasionally the cable is not severed but still damaged in some way. In this instance it is picked up between the two repeaters and cut open for testing. Some of the tests that can be conducted are capacitance measurement, insulation resistance and loop tests in addition to the pulse echo test to the nearest repeater. There are also facilities on board the ship for X–raying cable and developing photographs.

JOINTING

If a new section of cable has to be joined then the old one is stripped back to expose the centre conductor and a steel ferrule crimped over the two centre conductors. Next, the polyethylene insulator needs to be restored.

This is achieved by injecting it into a mould so that it joins with the insulator on both sides, Fig. 32. At this stage X–ray photographs are taken to ensure that the work is satisfactory.

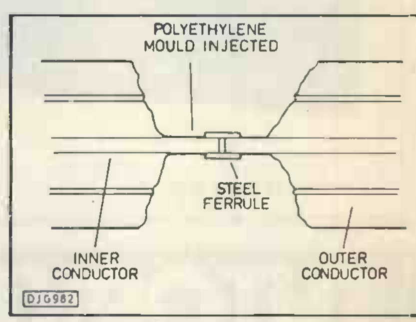


Fig.32 *Jointing cable.*

Next the outer conductor which is copper or aluminium needs to be restored. This is rivetted and a polyethylene sheath moulded once again. If there are armour wires, these are spliced over the top, followed by an outer sheath.

Cable impedance is around 50ohm to 60ohm and is not optimised since it is used for so many different types and level of signal. An approximate formula for attenuation is $m\sqrt{f} + nf$ dB/km, where m and n are coefficients.

Attenuation is inversely proportional to the diameter and m is derived from the values of the conductor. Since m is greater than n (which is derived from the dielectric values), n becomes important only above 14MHz.

SUBMERSIBLES

There are two unmanned submarines: Scarab (submerged craft assisting repair and burial) and Seadog. The first is American, the second British. The cable ship mentioned above as well as Seadog are owned by British Telecom.

Scarab and Seadog are similar except that Seadog crawls on the seabed while Scarab swims. Both use cameras for eyes and these submersibles are used for recovery of damaged cable as well as post lay burial. Some of the older cables that were not originally exposed to fishing and shipping activities are now being buried to protect them from these hazards.

Scarab, a submersible craft, entered service in 1976 and can work down to 1000 fathoms digging up cables, reparing them and then reburying them. It can dig to a depth of 1.25m.

Even before Scarab there was an American sea plough which was used to bury the TAT3 cable in 1963. It weighed 15 tons and had dimensions of 7.3 x 3.3 x 2.7 metres. For three months it crawled at depths of 90m burying 130km of the UK end which terminates at Widemouth.

Submersibles are not the only things capable of a decent burial. If a pipe is slung over the side of a ship and a jet of air fired through it, a channel up to 2m deep can be created in a sandy seabed. The cable is drawn in immediately behind the jet and the channel caves in almost instanteously.

However, to recover and repair a buried cable it is better to have a dog fetch it and Seadog will be described briefly. This creature looks like a battle tank, complete with caterpillar tracks and came into service in 1983.

The vehicle is approximately 8 x 5 x 4 metres and weighs 15 metric tons. It is made of plastics and aluminium and can work at depths of 300m and currents up to three knots.

Four, 2–foot propellors on the sides produce horizontal propulsion and these are driven by hydraulic motors producing a 645kg thrust. Vertical thrust is provided by one propellar fore and two aft. These propellors enable free swimming and the tracks enable crawling on the seabed.

An umbilical connects Seadog to the mother ship which provides power and monitors the returned data. The cable weighs 8kg/m and has a strain limit of 45 tons.

There are three video cameras and one 35mm stills camera. The videos are mounted fore, aft and one on the manipulator arm. The manipulator arm can lift up to 90kg and is used for cable recovery.

CABLE MAINTENANCE

No striplings here, these are the big boys both in terms of voltage and weight.

Before the second 132kV Isle of Wight cable was laid, old telegraph cables were being recovered and the first 132kV cable was picked up by mistake. A cutter with a force of 27 tons was required to sever the damaged cable and simultaneously a new section was run out from the mainland.

It took eight hours to recover 1055 metres of cable and about six days to joint the new one. During these operations, the cable was held firmly and maintained under oil pressure. The insulation and screens were stripped off and the centre conductors welded. A lead sleeve was applied and the surrounding air extracted. Degassified oil was pumped around the joint and a lead patch was placed over the oil nipples.

The joint was then reinforced, anticorrosives were applied and the armour welded together. Close whippings of yarn followed and to test the cable, 264kV was applied for 15 minutes.

SUMMARY

The history of submarine cables has been traced starting with the earliest telegraph cable and moving onto modern coaxial cables and optical fibres.

The volume and diversity of traffic has also grown from telegraphy to telephony, telex, data, sound and vision including videoconferencing. The impact of new technologies like circuit multiplication as well as the competition from satellites has been considered.

A brief history of the evalution of the UK telephone network was included as well as a survey of old and new cables. CANTAT 2 and the 14MHz and 45MHz systems were described in more detail and a brief description of optical communications was given.

Power cables are in a class of their own even when it comes to maintenance. Some idea was given of fault finding techniques on telephone cables. Cable ships were described and the increasing use of submersibles for maintenance was highlighted.

The future will be very exciting with digital techniques being developed for both cable and satellite. How well cables will fight off the satellite threat remains to be seen. PE

GLOSSARY OF TERMS

adpcm	adaptive differential pulse code modulation
ANZCAN	Australia, New Zealand, Canada cable
apd	avalanche photo-diode
CANTAT	Canadian – Transatlantic
CME	circuit multiplication equipment
CS	Cable Ship
dsb	double side band
fdm	frequency division multiplex
hypergroup	900 channels, 15 supergroups
iru	idefeasible right of user
laser	light amplification by stimulated emission of radiation
led	light emitting diode
mastergroup	five supergroups
pcm	pulse code modulation
pin	positive intrinsic negative
psf	power separation filter
PLUTO	Pipeline Under the Ocean
regenerator	inserts new pulses for old in a digital system
repeater	amplifies an analogue signal
supermaster-group	900 channels, three mastergroups
supergroup	60 channels, five groups
SEA-ME-WE	South East Asia – Middle East – Western Europe
ssb	single side band
TAT	Transatlantic
translation	moving a band of frequencies into a higher or lower band

UNSUNG GENIUS

The genius of some inventors is sometimes unknown except to their closest colleagues, and yet their creativity can have had a profound influence on our daily lives.

Samuel Ruben was one such scientist, and who died in July 1988 at the age of 88. He had close connections with Duracell Batteries and was the inventor of some fundamental electronic devices. Yet he was practically unknown outside of Duracell.

Among the items invented by Ruben were the dry plate rectifier and the dry electrolytic capacitor. These have been familiar now for many decades, but probably few know from whom they had originated, despite the fact that he was thus virtually responsible for the change from battery powered to mains powered radios in the 1920s.

In association with Duracell's founder, P.R. Mallory (after whom the original Mallory company was named), Ruben also developed the first practical design for an alkaline cell. His mercury battery arrived just in time for World War Two, during which the cell's consistent voltage and resistance to deterioration under adverse conditions made it the preferred power source for battery powered military equipment.

Despite being self taught and without formal qualifications, Samuel Ruben was awarded many academic honours, including three honorary doctorates. At the time of his death he was professor of physics at Reed College in Portland, Oregon, USA. **Ed.**

PLD PROGRAMMER

Part Two By Chris Kelly and Steve Pattinson

PROGRAMMED FOR A SENSE OF ACHIEVEMENT

Concluding a low cost project board for simple diy programming of the PLS103.

Most of the components are situated on the main pcb shown in Fig. 9. First mount the small components, such as resistors and diodes, as some of these fit tightly between some of the taller components such as the multi-turn potentiometers. Take care in observing the polarity of the diodes and electrolytic capacitors. Insert links LK1 and LK2 which are located upper centre.

A panel case of 12in x 6.5in x 3.5in minimum depth at the rear is suitable for housing all the components and providing sufficient space for an uncluttered panel lay-out.

The switches, leds and 28-pin zif (zero insertion force) socket are mounted on the case front panel. The zif socket is soldered to a sub-assembly pcb as shown in Fig. 10, which also supports pull-up resistors R42 to R50.

Wire between panel-mounted components, zif pcb and the main pcb using ribbon cable where convenient. Wire the rotary switch and led connections first, followed by the remaining wires. Ensure there is sufficient slack in the wiring for the panel to stand upright from the case.

Ensure that the wire-ends and resistor leads are cut flush to the reverse side of the zif pcb (note, the non-solder side). Apply double-sided tape around the zif socket, which will also act as an insulator from the aluminium panel, and firmly secure the assembly to the underside of the panel with the zif socket protruding through.

Mount the mains connector, mains fuse holder and optional neon mains indicator at the left rear of the case. Finally, secure the transformer and capacitor C4 to the base of the case to the left of the main pcb and complete the wiring between these components.

SETTING UP

Before inserting your first pld for programming, the voltage outputs of the regulators need setting up.

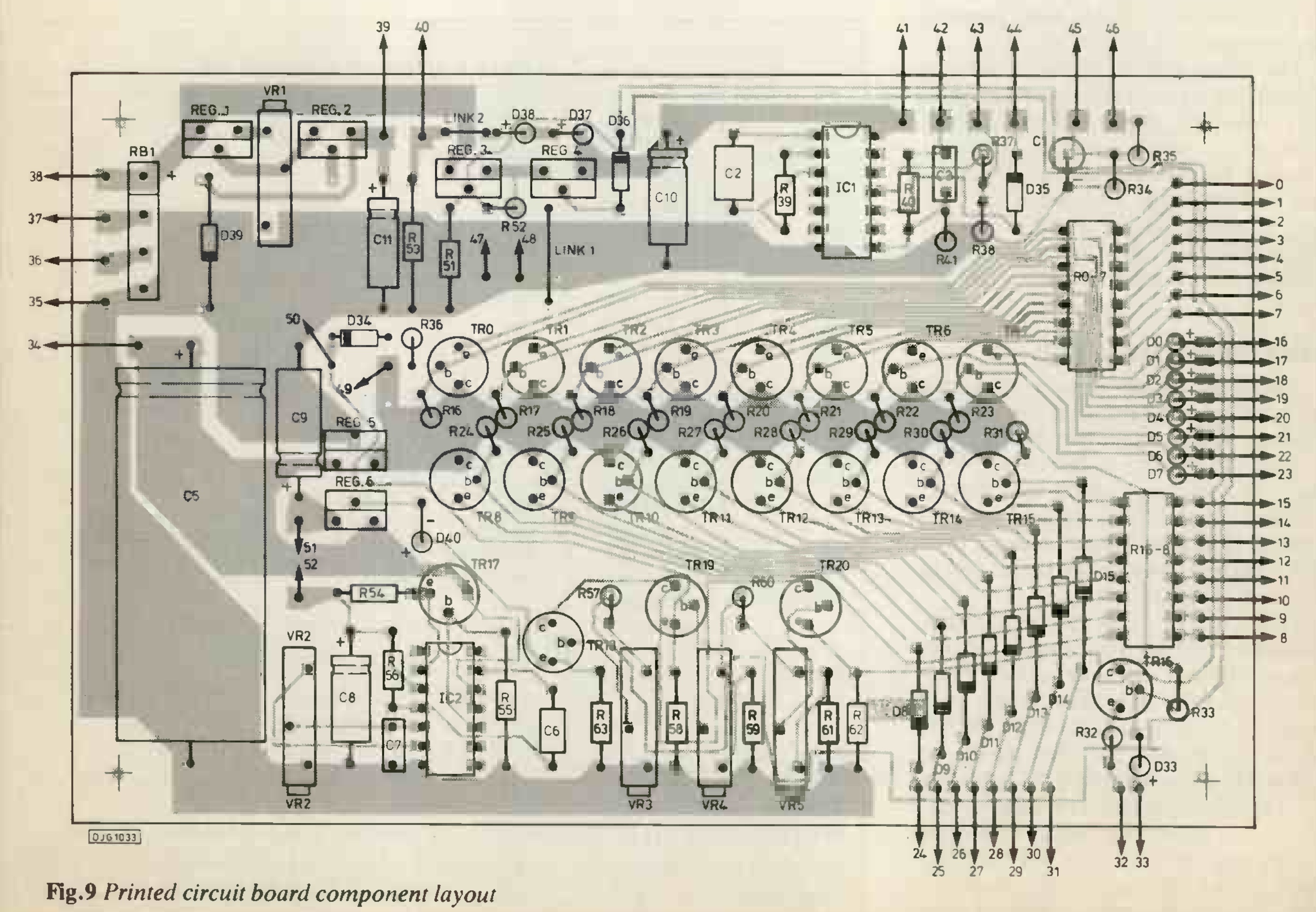


Fig.9 *Printed circuit board component layout*

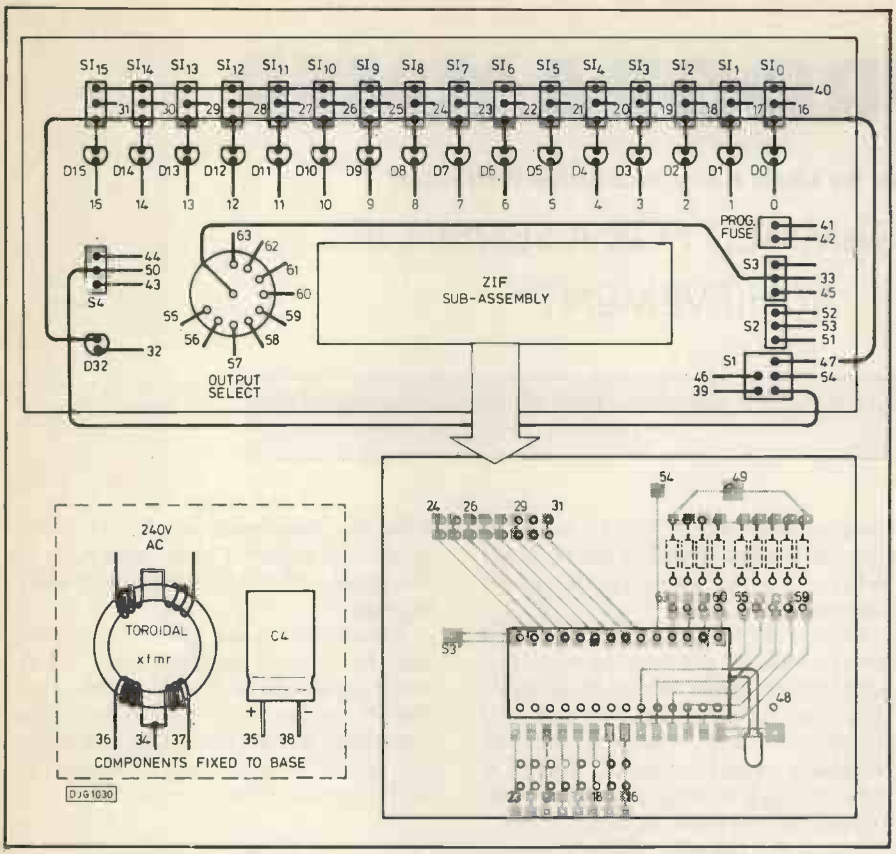


Fig.10 *Interconnection details*

Switch on the power with the zif socket empty and set the voltages within the limits given in Table 2.

VR2 to VR5 set the 5V, 8.75V, 17V and 10V respectively. VR5 also provides approximately 11.8V to IC1.

The 17V supply is current limited to 150mA. To set the correct current limit, first switch off, then connect a 22 ohm resistor in series with an ammeter between the 17V output and 0V. Wires can be temporarily soldered in place for this purpose. Switch on and quickly adjust VR1 until the current reading is 150mA. Switch off and remove the test wires.

PROGRAMMING A PLD

Assuming all has gone well during construction and setting up you are now ready to program your first pld.

With the power off, insert the pld in the zif socket, ensuring correct orientation, and clamp the legs with the locking device on the zif socket. Then follow the program/verify flowcharts of Fig. 11 and Fig. 12

Program and verify an output first, followed by all the inputs related to that output. Follow the arrows marked 'H' on the flowchart of Fig. 12 for a high level input to be programmed (this actually blows the In fuse for that input), or follow the arrows marked 'L' for a low level to be programmed (this blows fuse $\bar{\text{I}}\text{n}$). For a 'don't care' state follow the arrows marked '–' which will take you through the 'H' and 'L' sequences to blow both $\bar{\text{I}}\text{n}$ fuses. Repeat the procedure for all outputs and related inputs to be programmed for your particular application. Unused outputs and their related inputs need not be programmed and are available for any future modifications to the pld programmed logic functions.

Remember, unprogrammed devices have low polarity outputs because the X fuses are intact and therefore if a high polarity output is required the output needs programming to blow the appropriate X fuse. The inputs of unprogrammed devices have both In and $\bar{\text{I}}\text{n}$ fuses intact for each output, one of which is blown for a logic level and both for a 'don't care' input. Full verification of the states between a particular input and output can be made using Table 3.

In practice, we found that input fuses blow with the first try but the output fuses occasionally proved to be stubborn and a number of attempts were required. Multiple presses of the 'prog fuse' button may be necessary with no apparent harm to the devices. We did encounter a certain amount of variability between batches of plds and one device was particualrly stubborn about yielding its output polarity fuses. If you have such problems, return to the setting up procedure and increase the 17V current limit in steps of 5mA until fuses blow satisfactorily.

A word of caution during programming. With this being a manual programmer, the time taken to program a complete device is much longer than with commercial programmers, especially when the user is learning. Do not leave programming voltages switched to the device too long. If it

START AND END LOCATIONS

Wire No.	On main pcb	On front panel	On zif sub-assembly	On Xfmer	On Cap C4
0 to 7	Upper right	D0 to D7			
8 to 15	Lower right	D8 to D15			
16 to 32	Upper right	SI0 to SI7	Lower centre		
24 to 31	Lower right	SI8 to SI15	Upper left		
32	Lower right	D32			
33	Lower right	Switch S3			
34	Upper left			Sec centre	
35	Upper left				neg
36	Upper left			Sec top	
37	Upper left			Sec bottom	
38	Upper left				pos
39	Upper left	Switch S1			
40	Upper left	SI0 to SI15			
41,42	Upper right	Fuse switch			
43,44	Upper right	Switch S4			
45	Upper right	Switch S3			
46	Upper right	Switch S1			
47	Upper centre	Switch S1			
48	Upper centre		Lower right		
49	Upper left		Upper centre		
50	Upper left	Switch S4			
51,52	Lower left	Switch S2			
53		Switch S2	Upper left		
54		Switch S1	Upper centre		
55 to 63		Rot switch	Upper centre		
LK1 & LK2	Upper centre				

Table 3
WIRING DETAILS
The main pcb is divided into six areas for reference.

Upper left	Upper centre	Upper right
Lower left	Lower centre	Lower right

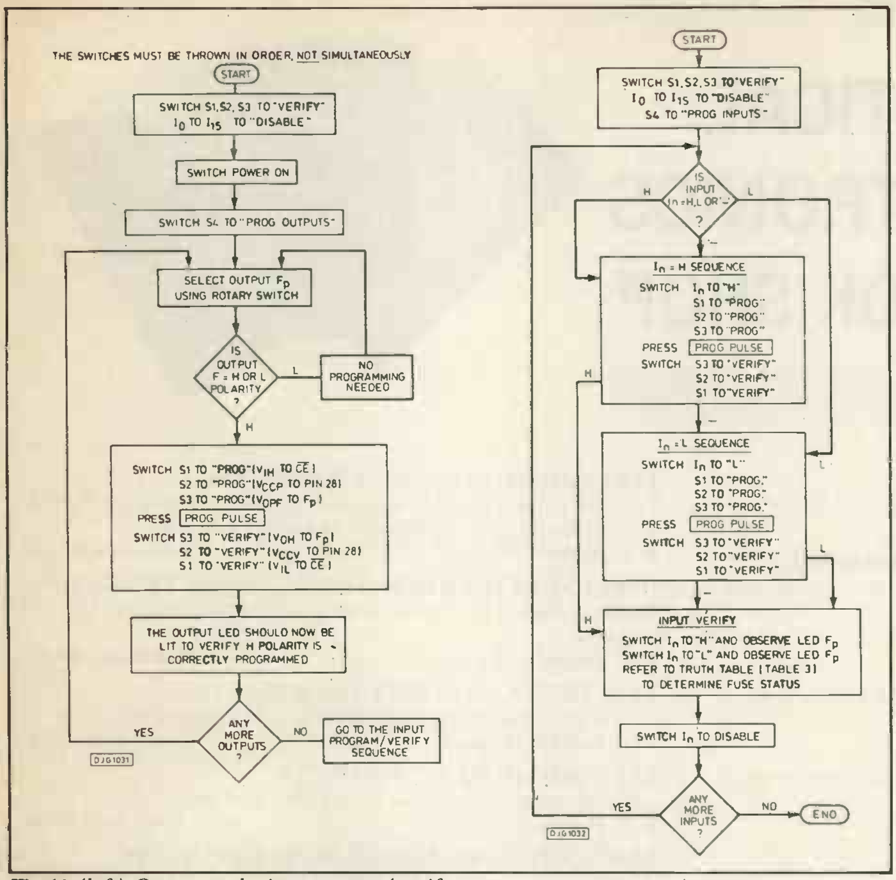


Fig.11 *(left) Output polarity program/verify.*
Fig.12 *(right) Input program/verify sequence.*

	Input In switch position L	H
Output when Fn programmed H and input programmed H	L	H
Output when Fn programmed H and input programmed L	H	L
Output when Fn programmed L and input programmed H	H	L
Output when Fn programmed L and input programmed L	L	H
Output when Fn programmed H and input programmed 'don't care' (—)	H	H
Output when Fn programmed L and input programmed 'don't care' (—)	L	L
Output when Fn programmed H and input 'unused' (O)	L	L
Output Fn when programmed L and input 'unused' (O)	H	H

Table 3: Full verification table

appears to be getting hot, switch off for a while and break the programming into shorter sessions.

After you have followed the flowcharts once or twice the sequence of operations will seem logical and easy to follow. You should have a working device within minutes, accompanied with the same sense of achievement when you programmed your first microprocessor. Steve Pattinson, co-author of this project, has kindly offered to supply readers with a durable front panel overlay and drilling template for £4.50 plus 50p p&p. Write to him at 34 Mountway Road, Bishops Hull, Taunton, Somerset, TA1 5DS.

PE

PLD BACK ISSUES

For those who missed the two articles on the theory of programmable logic devices we have a limited number of back issues available from November and December '87. They are £1.50 each, including UK postage (£2.00 overseas)

DOUBLE LASING

I know someone who is responsible for training staff at her office in the gentle art of using computers.

Recently she showed a temporary office girl how to print out hard copy from a computer to a laser printer. Initiation over, the temp was left to print out single copies of numerous documents. Job successfully done, friend then asks temp to make several copies of another document.

A few minutes later temp comes back in distress. "Please miss", she cries, "it's eaten them!"

Friend marches temp back to laser printer to establish the nature of its hunger. It had indeed consumed the copies. But that's hardly surprising since temp had neatly interleaved carbon paper with the requisite number of plain sheets and fed the complete bundle into laser printer. Unlike typewriters, but more like photocopiers, laser printers don't work that way, and certainly don't appreciate a non-standard diet.

The engineer who came to sort out the mutilated mess didn't appreciate it either. We don't yet know what friend's accounts department thinks of the episode. **Ed.**

PE PRACTICAL ELECTRONICS
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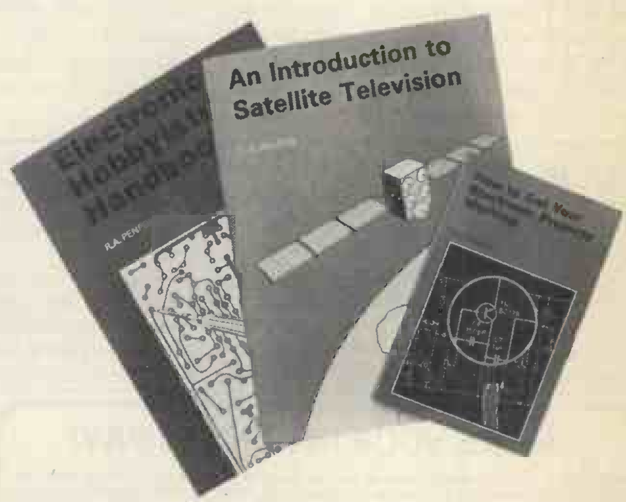

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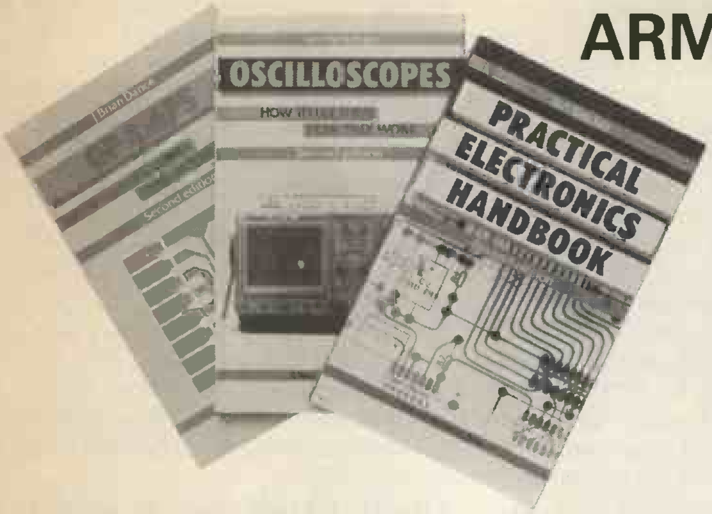

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OF DISCS AND DIGITS

BY TOM IVALL

HIS MASTER'S MEGABYTE

God may have created the brain, but man is doing his best with the gramophone record.

Before 1988 runs out I'd like to mention two further anniversaries which have more than average significance for the world electronics industry.

In the January issue I reminded readers that 1988 was the centenary of the discovery of electromagnetic waves, and argued that this led to the formation of the radio industry which in turn gave birth to the electronics industry. After a lot of celebration in the press and on radio and tv, you probably haven't failed to notice that 1988 is also the centenary of the invention of the disc gramophone by Emile Berliner.

The other anniversary is less well known. This year is the jubilee of pulse-code modulation, which Alec Reeves of STC patented in 1938. With the benefit of hindsight we can now see a technological link between the inventions of Berliner and Reeves – in modern information technology.

Of course the first disc gramophones or 'talking machines', were entirely acoustic devices. But the convenience and popularity of the disc record, compared with the earlier Edison cylinder, produced a revolution in home entertainment. The talking machine became predominantly a music machine. Such popularity was a spur to further technical and commercial development, and the most important step was the change to electrical recording and reproduction.

Lee de Forest had invented the triode valve in 1906 and this, followed by the tetrode and pentode, became cheap and plentiful in the 1920s with the advent of broadcasting. The possibility of electronic amplification gave us the record player and radiogram.

Sound reproduction equipment became a substantial part of the consumer electronics industry and led to the almost separate activity of hi-fi. But from the point of view of the Berliner-Reeves link method above the most significant thing was that the gramophone record was a new way of storing information. When digital recording, cd and the video disc eventually arrived this fundamental point became very obvious.

Any new technique for recording and storing information is a further opportunity for human development – from writing on clay, stone, ivory and papyrus to modern printing on paper and electronic storage. Quite apart from its practical help in producing the material basis of life, information storage – from the memory traces of the wandering bard to modern sound, video and text media – is the physical means by which we pass on the culture. Without it we would remain primitive creatures, perhaps intelligent but merely repeating the pattern of the species. Knowing nothing of the past, we would be unable to build on previous experience.

The arrival of gramophone records, of course, provided the commercial incentive to the development of magnetic recording. Although many audio and video tape cassettes are intended as permanent, play-only records of entertainment material the fact is that the magnetic oxide coating allow writing as well as reading. This characteristic, plus all the sound recording/playing technology by then available, made magnetic recording an attractive form of bulk storage for digital computers. Magnetic drums arrived first, followed by magnetic tapes, floppy discs and hard discs.

Here we come to information technology, broadly a marriage of computers and telecommunications. Alec Reeves developed pulse-code modulation mainly with the idea of using the constant-amplitude, on-off pulses of telegraphy to make telephony digital, thereby beating the ever-present noise problem. As we know, digital telephony, and digital everything-else-you-want-to-send, is now commonplace. But in the process Reeves had constructed the first working analogue-to-digital converter.

This device was the practical embodiment of a basic principle at the heart of information technology: that all information, whatever its original form, can be represented as patterns of binary choices – what we now call binary digits or bits. Everything can be digitised. The patterns of bits can be frozen in static form in magnetic or semiconductor memories, or they can be sent along wires as trains of pulses. Using both these forms of existence, the bits can also be manipulated in logic circuits or digital processors. So storage, processing and transmission are the three basic techniques of information technology.

One of the problems of magnetic storary is its serial, time-dependent nature. There has to be relative mechanical movement between the magnetic field and an electrical conductor to make it work. This limits the speed at which information can be written-in or read-out. But the limitation has spurred on the development of the semiconductor memory. Originally intended for high-speed, low-capacity storage, it is now getting more and more capacious in its ability to hold information.

By 1988 the dynamic random access memory chip (dram) has become capable of storing 4 million bits (megabits). This doesn't seem much compared with the 10,000 to 20,000 megabits of read-only bulk storage devices such as optical discs and holographic memories, or the 150,000 megabits of videotapes. But the semiconductor storage method allows rapid access, and such chips are now being used for holding complete television fields or musical phrases or other batches of information which have to be handled in real time.

The human brain – the archetype of all memory whether natural or artificial – is estimated to have a storage density of 1000 megabits per cubic centimetre. Whether this figure is accurate or not, electronic engineers will have a hard job to rival the brain's combination of storage density and flexible processing performance. Alec Reeves, who died in 1971, suggested that a storage density of 1 Gbit per cubic centimetre would be an achievable target, though I don't think anyone has got there yet.

Speculating wildly, I suppose the ultimate in artifical memory would be a binary cell formed by a single atom of some material. Theoretically this could be switched between two (binary) states: charged positively to become a cation, and charged negatively to become an anion. I will leave it to PE readers to think out how this could be done in practice. Answers on a post-card please.

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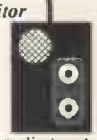

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Heat Sinks by Stephen Knight. The theory and practical application of heatsinks. **February**
I Don't Always Agree... by Wayne Green. A personal view of how educational videos might change the world. **August**
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Microprocessor System Development by Tim Watson. How the right tools and techniques can greatly simplify the integration of hardware and software. **September-October**
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Recalling History – Part Two by Barry Drake. Concluding the history of the telephone, and a look to the future of the all-electronic exchange. **January**
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Regular Features

Editorial by John Becker. Monthly views and comments from the Editor.
Industry Notebook by Tom Ivall. Monthly series looking at the electronics industry.
Leading Edge by Barry Fox. Monthly series looking at the technology behind the news.
Spacewatch by Dr. Patrick Moore CBE. Monthly series of astronomy reports.
Bazaar. Monthly readers' free advertising service.
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Chip Count. Monthly list of new chip details received.
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News and Marketplace. Monthly series detailing new products and services.
Readers' Letters. Monthly series expressing your views, and offering a few replies.

Summary Points 1988

Amstrad ROM Expansion (Jun 88)
IC2 is a 74LS374.
Egg Timer (Jan 88)
The PCB track shown for Fig. 2 should be amended so that: IC4 pins 9 and 13 are connected; IC2 pin 2 goes to IC2 pin 10 and not to Pin 11. Polarity of D1 and D2 should be reversed. In Fig 4 labels to TR9, 10, 16, 15, 14, 13, 12, 11 should read TR16, 15, 14, 13, 12, 11, 10, respectively.
Mains Modem (Jun 88)
C1 should have a working voltage of at least 250Vac.
Recalling History Part 2 (Jan 88)
Fig. 9. Page 41. Brown lead of 706 telephone should go to point 3, not to point 4. The original Telecom drawing was incorrect!
Semiconductors Part 7 (Jun 88)
Amend parts list so that R1 is 4k7. In Fig. 68 the two 100 ohm input resistors should be 100k.
Upstairs Alert (Mar 88)
(Ingenuity Unlimited). TR3 may be a ZTX 300 or similar.
Vidoe Enhancer (Dec 86)
In Fig. 5, polarity of C4 should be reversed.
Video Fader (Jan 87)
In Fig. 5, polarity of C2 should be reversed.
Vocals Eliminator (Jul 88)
Resistors R7-R10 should all be 100k. The symmetry of the pcb track layout has caused some confusion. It does not matter which way up it is printed providing IC1 is inserted so that the +V lead goes to its pin 4, and the OV line goes to its pin 11.

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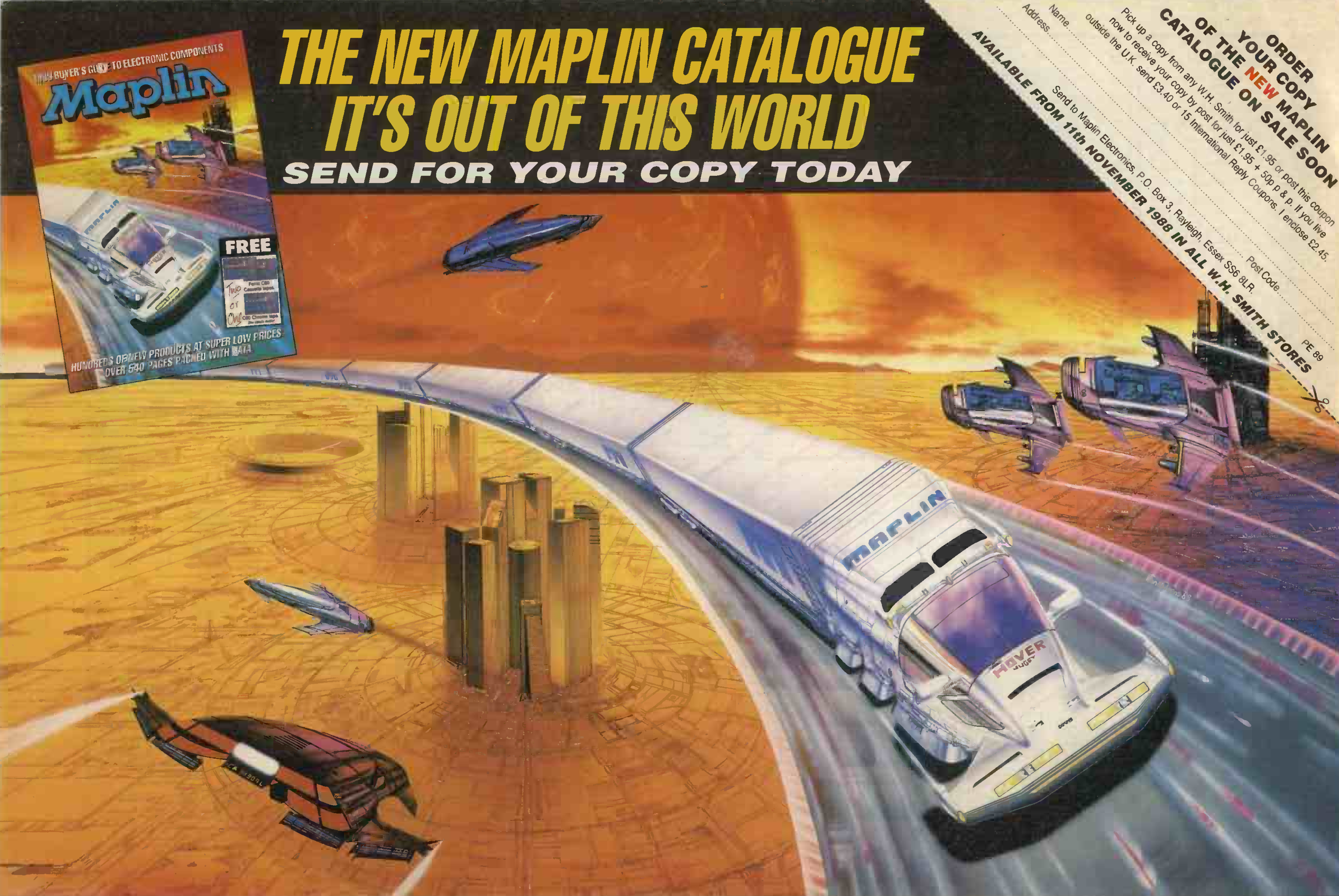

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