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WHAT'S NEW . . .

Low cost logic analysers with powerful features

The K40/50, from Gould, enables both synchronous and asynchronous data to be captured on all channels, and enables accurate timing comparisons to a resolution of 10ns on up to 12 channels—features only available previously on mid-price logic analysers.

Features of the K40 include 32 channels of state at 15MHz, or 16-state with 16 timing at 25MHz. The K50 has 48 channels of state at 15MHz. Both instruments have a memory of 2K per channel and triggering through four levels of Trace Control with Find, Wait, Stop, Sample, and Repeat commands to help solve complicated hardware-software problems.

Weighing only 6·7kg, the K40/50 is easily portable. Both instruments are supplied with probes, probe connectors, power cord, and operating manual. Options include RS-232-C and Centronics interfaces.
Details from: Gould Electronics Ltd., Instrument Systems, Roebuck Road, Hainault, Ilford, Essex IG6 3UE.

Single colour terminal card for any RGB monitor

Semi-graphics and text for any RGB colour monitor can be achieved using a Single card available from Quantech.

The 8085 based single board needs only an ASCII keyboard and an RGB monitor to make a complete computer console, advertising system or on-line bulletin board.

The on-board software command set has over 170 commands including: Scroll up/down/left/right. Wrap up/down/left/right. Insert or delete character/line/column.

40 wide column includes 1-of-8 colour selection for foreground, background, backdrop, and border whilst both 40 and 80 column modes allow control over flashing, inverse, underline, etc. All attributes are parallel and there are no wasted characters.

As well as the usual screen scroll, there are commands to scroll, save, restore and erase user-definable areas. Entire lines or block areas may be erased or copied in a single command.
Details from: Quantech Ltd., 11 Lansdowne Terrace, Gosforth, Tyne & Wear NE3 2HN.
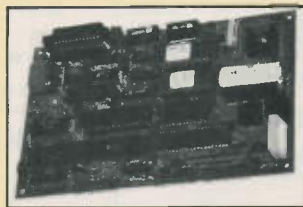
Flexible and expandable Z80 based SBC

The latest SBC from J.P. Designs features a Z80A microprocessor running at 4MHz, Z80 PIO providing two 8-bit input/output ports, 2K to 32K of EPROM decoding and 64K of fast dynamic RAM. The unit also features bank switching capabilities allowing soft monitor programs to be installed, e.g. CP/M.

Additional sockets for a further PIO, SIO or DART, and CTC have been incorporated to increase system flexibility. All microprocessor bus signals can be accessed via an IDC header making expansion simple.

The compact 200 × 150mm card requires only a +5V supply and comes complete with user notes and circuit diagram at a cost effective price of £195.00 + VAT.

Also available from the same source are a range of SMPSUs which offer 45W continuous power ratings and are available in single Eurocard sizes.
Details from: J.P. Designs, 37 Oyster Row, Cambridge CB5 8LJ.
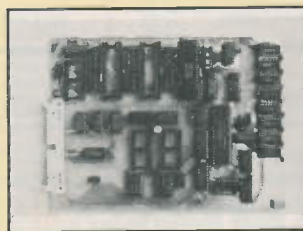
Weigh-in

Bolton Electronics Ltd. launched in March their BE-1 load cell monitor as a stand-alone product after two years' proving units installed in their complete systems. The BE-1 is an SBC based system designed to provide the full range of features called for in versatile high-accuracy electronic weighing systems.

The unit will power up to 4 load cells and includes a 4-digit display (−1999 to 9999) with switchable decimal points. Its flexibility is enhanced by the provision of switches to select 4 ranges of gain/span (max. sensitivity 0·1 microvolt), and 8 ranges of offset/zero allowing tare loads up to 90% of load cell output. In addition a 1Hz active filter can be switched into the system to reduce the effect of vibration, and an "auto zero tracking" facility can be selected. In addition a range of on-board options are available which make use of the computers power.
Details from: Bolton Electronics Ltd., Wheatsheaf House, Market Street, Westhoughton, Bolton BL5 3AH. Tel: 0942 810304.
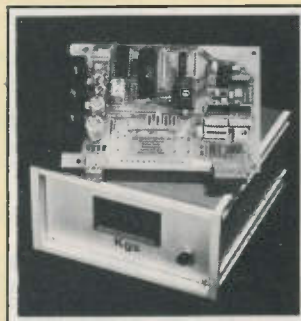
Workdek

The Workdek is a purpose designed workplace unit specifically aimed at model engineers, watchmakers, radio and electronics enthusiasts. The desk, supplied flat-pack, is a sturdy freestanding item of furniture in an attractive chocolate and cream colour scheme with a work area which can be closed and locked away for security.

The desk is supplied in flat-pack form for easy self-assembly and it includes two sets of drawer storage units, electrical power supplies consisting of two mains sockets and 12V terminals for miniature power tools. An optional extra panel provides a smooth, regulated and variable d.c. supply up to 30V together with a voltmeter. The work area includes interchangeable work surfaces of a laminate and a soft vinyl (other options possible) together with provision for holding clamps and additional tooling.
Details from: Elek Ltd., P.O. Box 32, Winchester, Hants SO22 5LX. Tel: 0962 56452.
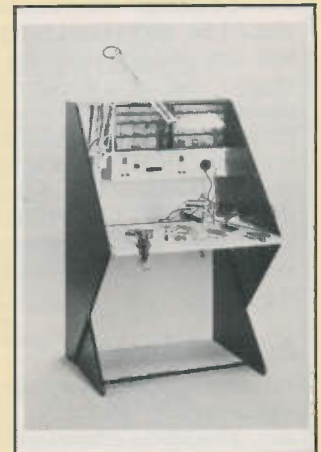
Bench Meter

Electronic Brokers has introduced the Thandar TM451 bench portable multimeter which has a 200mV to 1000V range and a basic d.c. accuracy of 0·03%.

The instrument features a clear $4\frac{1}{2}$ digit liquid-crystal display, with 11mm high characters incorporating legends (mV, A, etc) to indicate functions selected. The display has a blinking overrange indication and low battery warning.

The TM451 has a sampling rate of 2·5 times per second, full autoranging plus manual range selection, a sample hold function on all ranges, polarity indication, and audible continuity bleeper.
Details from: Electronic Brokers Limited, 140–146 Camden Street, London NW1 9PB.
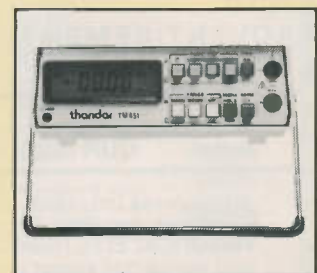
WHAT'S HAPPENING . . .

8mm Automatic Cleaner

With the increase in sales of 8mm cameras and video recorders Bib are now making available the new VE-42 8mm Automatic Video Cleaner which was recently released in the USA at the Winter Consumer Electronics Show.

The cleaner features abrasive-free Polyester spun bonded material that can be used wet or dry. Oxide particles, dust and other contaminants are removed by simply running the cleaner forward in any 8mm machine for ten seconds. Each portion of the cleaning material passes through the tape travel path only once and there is no possibility of debris being redistributed in the machine. Each cleaner is good for twenty-five fresh cleanings.

Details from: Bib Audio/Video Products Ltd., Kelsey House, Wood Lane End, Hemel Hempstead, Herts HP2 4RQ. Tel: 0442 61291.

Static-Free Desolderer

OK Industries are now supplying the DP3, hand-operated, static-free desoldering pump and tip at only £3.16 (inc. post, packing and VAT). A recent addition to the company's anti-static range, it has been manufactured in line with exacting UL and MIL standards.

Furthermore, it satisfies MIL/B/817025 second barrier electrostatic-free material requirements and has an easy-to-clean and change bayonet-type conductive tip as standard. A high-temperature-resisting Teflon tip is also available for an extra 71p.

Details from: OK Industries UK Ltd., Dutton Lane, Eastleigh, Hants SO5 4SL. Tel: 0703 619841.

New mini printer for portable equipment

Developed by Epson, a new series of mini shuttle printers are available designed for incorporation into portable/compact equipment. They combine high print quality and speed with low power consumption (200mA at 5V) and low cost.

The new range includes the M-180, 181, 182 and 183 printers. The basic 24 column M-180 provides a print speed of 1·5 lines per sec (LPS) (against the 0·71 LPS of the M-160) and the 144 dots per line (DPL). The M-181 will give 30 columns, 1–3 LPS and 180 DPL. The M-182 36 columns, 1·1 LPS and 218 DPL. The M-183 42 columns, 0·9 LPS and 252 DPL. All use the same paper width of 57·5mm.

The printers can operate in text and graphics mode. A compact control board, the
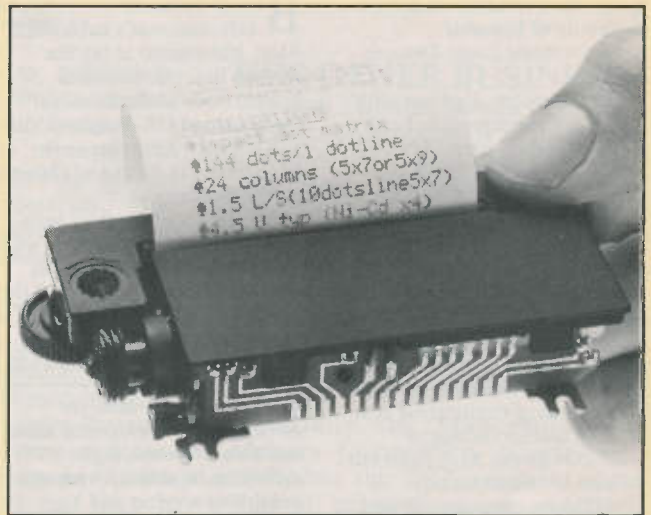
BA-180 and a single i.c., are available to simplify interfacing to the range.

The printers should meet the requirements of specific applications such as cash registers, calculators, taxi meters and computers.

Details from: Epson (UK) Limited, Dorland House, 388 High Road, Wembley. Middlesex HA9 6UH.

Rotary/Linear Tachometer

Both contact and non-contact measurements of rotary and linear speed can be taken with the new digital tachometer from M.S. Components.

The compact, battery powered, hand-held instrument covers speeds from 50 to 20,000 rpm in two switched ranges. Indication is by means of a $4\frac{1}{2}$ digit LED display and is accurate to ±1 digit.

Non-contact readings can be taken at up to 1 metre using the basic instrument or the optional optical sensor where visual access is limited.

The instrument is supplied complete with reflective tape, batteries and carrying purse.

Details from: M.S. Components Ltd. Tel: 01-670 4466.
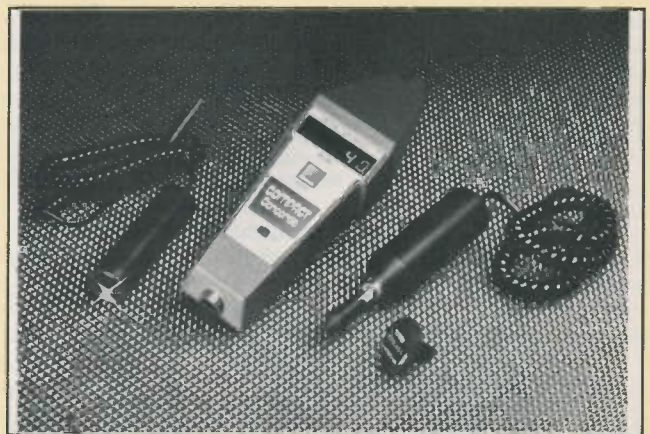
Ancient Mariner Wanted!

The London Electronics College, which celebrates its 80th anniversary this year, intends to mark the event by setting out on an international quest to find its oldest former student. The College, formerly known as the British School of Telegraphy founded in 1906, trained early Marine Radio Officers using the original Marconi wireless telegraph, some 300 of its students being at sea in 1912. Harold Bride, wireless operator on the *S.S. Titanic* at the time of the tragic iceberg disaster, and Thomas Cottam on the *S.S. Carpathia*, the first ship to acknowledge radio distress messages which saved so many lives, were both trained at the College.

Since its foundation the College reckons it must have trained some 5,000 students, many of whom will still be scattered over the remote parts of the world, both on land and at sea. In honour of the College's 80th birthday, a general signal "QSO" is being sent out to all former students asking them to get in touch again. It's just possible that some of those original 1906 Marconi wireless telegraph operators will respond to the call. Present-day staff and students would be delighted to welcome such visitors on a tour of inspection—just to see how much electronics has changed in the era of microcomputers and new technology.

Contact: M. D. Spalding. Tel: 01-373 8721.

WHAT'S TO COME . . .

EPLDs

Intel have recently released a family of Erasable Programmable Logic Devices (EPLDs).

These devices, together with the Intel Programmable Logic Development System (IPLDS), allow designers to create and verify custom CHMOS logic devices in a matter of minutes.

Debugging is no longer a problem because EPLDs can be erased in the same way as EPROMs. This significant difference to gate arrays results in considerably reduced costs since there is no Lead Time, no non-recurring engineering cost or time loss for redesigns.

EPLDs do not have fuses but instead are based on an EPROM-type storage cell and may be programmed, erased and re-programmed. The devices are manufactured using Intel's CHMOS IIE process and offer very high densities, increased functionality, low cost and have minimal power requirements.

Three Intel EPLDs are currently available and others will follow in the near future. The 5C060, 5C090 and 5C121 are CHMOS LSI Logic Circuit devices that can replace gate arrays requiring 600, 900 or 1200 gates respectively. Architecture is based on the 'sum of products' programmable structure, with a programmable AND array feeding into a fixed OR array.

Flexibility in accommodating logic functions is achieved through the provision of an OR gate width range, plus product term sharing. Additionally the EPLDs contain innovative architectural features which provide extensive I/O.

Rapid Silicon offer the IPLDS package which provides a powerful set of EPLD development tools. The system includes all of the software, programming hardware and documentation needed to convert a designer's hardware logic concept into a fully optimised, tested and documented device.

The IPLDS interfaces with and runs on an IBM PC or compatible, allowing the entire process to be accomplished at the designer's desk.

Details from: Steve Every, Rapid Silicon, Rapid House, Denmark Street, High Wycombe, Bucks HP11 2ER. Tel: 0494 26271.

Global Alert

British Telecom International's cableship, Alert, has started to lay the world's first international optical fibre undersea cable. Code named UK-Belgium 5, it will stretch 120km between Broadstairs in Kent and Ostend on the Belgian coast.

By 1990, a network of such cables will provide the UK with high-capacity digital links to Europe, North America and the Far East. The first digital transatlantic cable, TAT-8, is due in service by summer 1988.

"TAT-8 will be ideal for services such as integrated voice and data networks, high definition facsimile for remote publishing services and international video links for conferences and special events.

Anthony Booth, BTI's Managing Director, who sees a huge potential market offering enormous benefits to business customers, said: "Among the benefits to business communications will be the ability to transmit much greater volumes of information, at much higher speeds, than is now possible. This will be of particular importance to the financial community with its increasing use of computer information services, where data must be available at the touch of a button.

"TAT-8 will be ideal for services such as integrated voice and data networks, high definition facsimile for remote publishing services and international video links for conferences and special events.

"With TAT-8, BTI will be able to meet customers' international demands quickly—helping to keep London as the hub of Europe's financial and commercial community.

The Cableship Fleet

BTI operates three cableships, Alert, Monarch and Iris.

They survey and lay cable systems and maintain more than 18,000 nautical miles of cable within the UK and linking Britain with Europe and North America. Cableships are highly manoeuvrable and are designed to withstand heavy seas. They are frequently chartered by other cable owners and overseas telecommunications operators.

EMI—No Trouble

Following on from the article, April 1986, EMI means Trouble; maybe, now it needn't.

A series of liquid bond coats, each designed for use with specific plastics, is available through MCP Electronics to simplify zinc metallising.

Applied like spray paints, these coatings prepare the plastic for metallising and are arc-sprayed on to surfaces to help adhesion of a zinc layer to protect equipment from electromagnetic and RF interference.

The technique has certainly caught on in the USA, where some eight million square feet of surfaces such as plastic housings are arc sprayed annually.

This system offers several advantages over the traditional grit blasting approach to preparation, including consistency, economy, efficiency, and convenience. For example, while grit blasted plastics must be metallised within 24 hours, Tie Coats allow the process to be completed hours, days or even weeks later, a factor which considerably increases scheduling flexibility.

Details from: Components Division, MCP Electronics Ltd., 26–32 Rosemont Road, Alperton, Wembley, Middx. HA0 4QY.

COUNTDOWN

POINTS ARISING

CLOCK TIMER (MARCH 1986)

In the circuit diagram of the Clock Timer article TR8 should read 2N3252. Also on page 44 under the heading 'DIMMING' (2nd para), the sentence should read—TR7 is turned off and the whole output of IC5 is available . . . In the components list, D29 to D89 should be 0·5 inch.

PHOTOGRAPHIC TRIGGER UNIT (APR '86)

In the circuit diagram of the Photographic Trigger Unit, the microphone should have pin 3 linked to ground. The p.c.b. is correct. If only a two terminal microphone is available, the leads should be connected to ground and C3 with an additional 10k resistor from C3 micropohone to +4·5V.

INDUSTRY NOTEBOOK

BY NEXUS

UNSTABLE CONDITIONS

Older readers will know that the current recession—which is now thought to be past its trough—is only one of many that have plagued the semiconductor manufacturers. Booms and slumps have been occurring with almost boring regularity since the transistor was invented in 1948.

What I find rather strange is that all the clever people in this part of the industry have not been able to do anything to mitigate the worst effects of such economic cycles—by which I mean the flight of capital, the loss of jobs and the shortage of semiconductor devices which occurs just before each upswing in the trading cycle. After all, they are dealing with a man-made oscillation, comparable to the instability that can occur in servomechanisms, not an act of God or blind Nature.

To a mere observer of the scene it appears that the chip makers have not yet realised that the days of Fordism are over. You'll recall that Henry Ford told customers for his mass-produced cars "you can have any colour you like as long as it's black." This epitomises the standardization that helps economies of scale and makes possible extremely low priced products.

One result of this policy, and the cutthroat price competition that accompanies it, is that the market becomes saturated. A point is reached when the customers simply do not need or want any more of the products, however low the price and even if they are given away free. So the sales revenues coming back to the manufacturers are inadequate to cover costs and yield a reasonable profit.

Apart from custom-designed i.c.s, the semiconductor firms have been following the principles of Fordism slavishly and uncritically. They have reduced the prices of standard i.c.s to such a low level that customers can afford to use only a fraction of the available capabilities of very complex devices, ignoring the rest. This is surely bad economics, even if good business.

More percipient firms in other industries, such as clothing, have realised that flexible manufacturing methods, with very sensitive feedback from the market, are the right way to achieve stability of supply and demand. It's ironic that some of the modern tools they use to achieve success in flexible manufacturing, such as computers, programmable controllers, and data capture and transmission systems, are very much the results of integrated electronics. Perhaps the chip makers should look a little closer into their own back-yards for useful lessons to solve their trading problems.

MEDICAL ELECTRONICS

Edwards High Vacuum is perhaps best known as a manufacturer of pumps, valves and other such mechanical components for vacuum systems. It also builds vacuum pumping plants for television tube makers, and in the days before transistors and i.c.s it supplied a lot of equipment for evacuating thermionic valves. But this firm also develops and manufactures electronic instruments and controllers for use on vacuum systems. One of these vacuum systems, produced in various models, is the freeze dryer.

Edwards has recently supplied a large, electronically controlled freeze drying plant to the National Health Service for blood plasma processing. Its main purpose is to make the UK self-sufficient in a particular blood component, Factor VIII.

The NHS's Central Blood Laboratories Authority (CBLA) wants national self-sufficiency in Factor VIII partly to reduce the costs incurred in importing Factor VIII but mainly to reduce the risks of infection from AIDS which may occur with imported fractions.

Freeze drying is the best way of preparing Factor VIII for storage. Ordinary air drying would be useless, because even at room temperature it would disrupt the complex protein molecules and so destory the product. The Edwards freeze drying plant is installed in a new blood products manufacturing unit at the CBLA's Blood Products Laboratory at Elstree, Herts. In the process cycle, variables like pressure and temperature have to be controlled very accurately in order to safeguard the valuable product.

The process cycles are actually controlled at three levels. First is conventional manual control; next is programmed microprocessor control; and at the top is this same programmed control but supervised by a central computer system. Edwards don't make computers as such, so they have bought in a standard microcomputer to form the heart of the supervisory system. The order is worth £1·5 million.

BT'S OTHER BUSINESS

British Telecom, though primarily a supplier of services, is getting more and more involved in the manufacture and supply of telecommunications goods. At the time of writing it has just had clearance from the Department of Trade & Industry to go ahead with the proposed acquisition of a 51% controlling interest in Mitel, the Canadian telecomms manufacturer. Last year BT made an offer of £180 million for this stake.

Initially the Monopolies and Mergers Commission raised objections, but the DTI overruled these. Current negotiations are concerned with the safeguarding of competition if BT sells Mitel's products—mainly private automatic branch exchanges (PABXs)—in the UK. At present nearly 50% of Mitel's sales are in the USA, the world's biggest telecomms market, and BT obviously has a covetous eye on this.

During this period BT has also joined the European Computer Manufacturers Association (ECMA)—part of its strategy for becoming a big wheel internationally in information technology. Last year it made a licensing agreement with Bleasdale Computer Systems to produce and market the Bleasdale 6800 Unix microcomputer. This product is being made at a BT factory in Birmingham. There is also a factory in South Wales for consumer electronics, run by British Telecom Enterprises.

In addition to manufacturing, BT is beginning to get established as a supplier of telecomms goods. It has a chain of shops providing retail outlets—the most recent ones being in Newcastle, Plymouth and Southend—and also operates as a distributor of products from other manufacturers.

At a time when the UK is suffering 'an erosion of its manufacturing base' as the economists say, it's certainly good news that an indigenous British company is actually going into manufacturing rather than out of it. Some people believe that the country can exist largely on the supply of services —and our net invisible exports at £5 billion per annum are already greater than those of the USA—but this seems a risky policy. After being leader of the Industrial Revolution and the 'workshop of the world' for so long it doesn't seem very wise to throw all this away.

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Printer Leads can be supplied to any length.

DISC DRIVES

These are fully cased and wired drives with slim line high quality mechanisms. Drives supplied with cables manuals and formatting disc suitable for the BBC computer. All 80 track drives are supplied with 40/80 track switching as standard. All drives can operate in single or dual density format.

PD800P (2 × 400K/2 × 640K 40/80T DS) with built in monitor stand	£279 (a)
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2030CS Std Res	£380 (a)
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SUPERVISION III with amber/green option	£345 (a)
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MULTIFUNCTION COUNTER

PART 1 BY MIKE DELANEY

Build a professional standard counter for a fraction of the cost of a commercially available unit

ONE piece of equipment often missing from the average test-bench is the Frequency Counter. Scanning the small-ads in the usual magazines is sufficient to explain why this should be. Prices of quite low spec. instruments are quite high, so the amateur usually puts a higher priority on other equipment, scope, signal generator, etc.

Until recently, that is three or four years ago, the only way the amateur could build a counter was with discrete chips (if that is not a contradiction in terms!). Rows of TTL counter chips jostled for elbow room with transistor display drivers. These were overseen by a power supply which dimmed the lights when turned on, and could always double as a fry-pan when not needed by the proud builder. At the end you would be stuck with a piece of gear which was unreliable at best, and poor test gear is worse than none at all.

Thanks to modern technology (the dreaded MICRO-CHIP, yuk!) it is now possible to buy a single chip multi-function counter. Although the price, around £25, is fairly high, comparing what you actually get for the money shows this to be very cost-effective.

The chip used in this article is the ICM7216B, an 8-digit device, containing all the necessary circuitry to gate the input and drive the displays directly. All that is necessary to add is a power supply—5 volts @ 200MA, and a handful of resistors and caps, and a 10MHz counter can be realised very easily.

However (there is always one of them), to get full use out of the chip it is necessary to add a little more. This article will now describe how to construct a complete 200+MHz, multi-function counter at a fraction of the cost of a comparable ready-built one.

Throughout the design the main criterion has been simplicity in construction. Several test points have been provided to assist in fault finding if required. No problems should be encountered in getting the components, though it is certainly necessary to shop round for the 7216B. Some suppliers are charging up to £40 for it! Some suppliers are able to supply all the parts used, BUT—do spend some time looking round.

As with most home constructions, there are two ways for this instrument to look when completed—neat and professional or simply "home made". The choice is up to the builder. A little extra spent on a good case, facia and back panel is, I think, repayed in the pleasure got from owning such a piece of gear. Of course there is the temptation to judge the book by the cover!

The entire circuit can be conveniently broken down into five main sections, Power supply, Signal processing, Switching, Display and the 7216 itself. How these all fit together is shown in block diagram, Fig. 1.

POWER SUPPLY

The power supply is a straightforward affair, since the whole circuit requires only a single 5V line at 300mA.

Mains isolation and reduction is given by a 0V-9V5-0V-9V5 p.c.b. mounted transformer. Following this a bridge rectifier, two capacitors and an, almost, obligatory 7805 completes the power supply.

Despite the fact that the 7805 is 'virtually indestructible' (the manufacturer's words—not mine), a crowbar overvoltage circuit was included. It's the 'virtually' bit that is worrying!

In the unlikely event of the regulator going short-circuit the full supply voltage, about 12V, would appear on it's output. The life of the 7216, plus a few others, would then be short, if not spectacular! Thus it seemed a good insurance to invest a few pence, just in case.

The crowbar does require a little setting up and should also be tested prior to fitting any i.c.s. This will be dealt with in depth later.

SIGNAL PROCESSING

Two identical f.e.t.-input buffer amps are used to convert the input signals to a TTL level. The input impedence is very high (1M) and the output level is adjustable to give the required sensitivity.

Both the B-input and the low frequency from A is shaped by TTL NAND Schmitt gates after amplification. Attenuators of ×50 have been included, and are available via front panel switches. Changing the value of one resistor will enable the attenuation to be tailored to suit individual needs. The A-input is also routed to the divide by 100 prescaler. Cost was the deciding factor in choosing this particular device. Many prescalers are now available. The 8629, however, is cheaper than most, and is known to be very well behaved! That may seem an odd remark, but during the R&D stage many fruitless and frustrating hours were spent trying to cure prescalers which
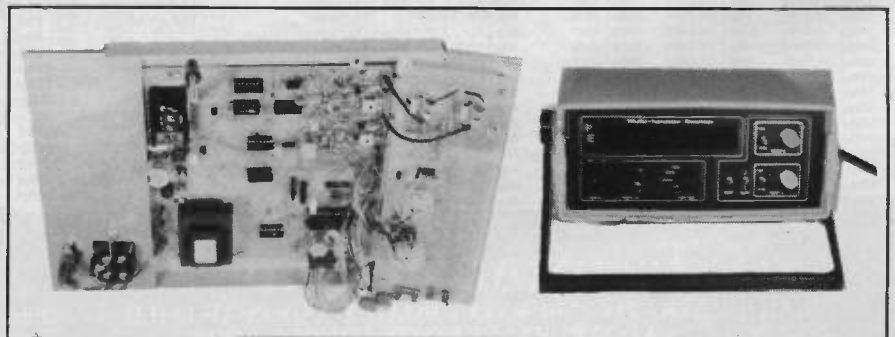

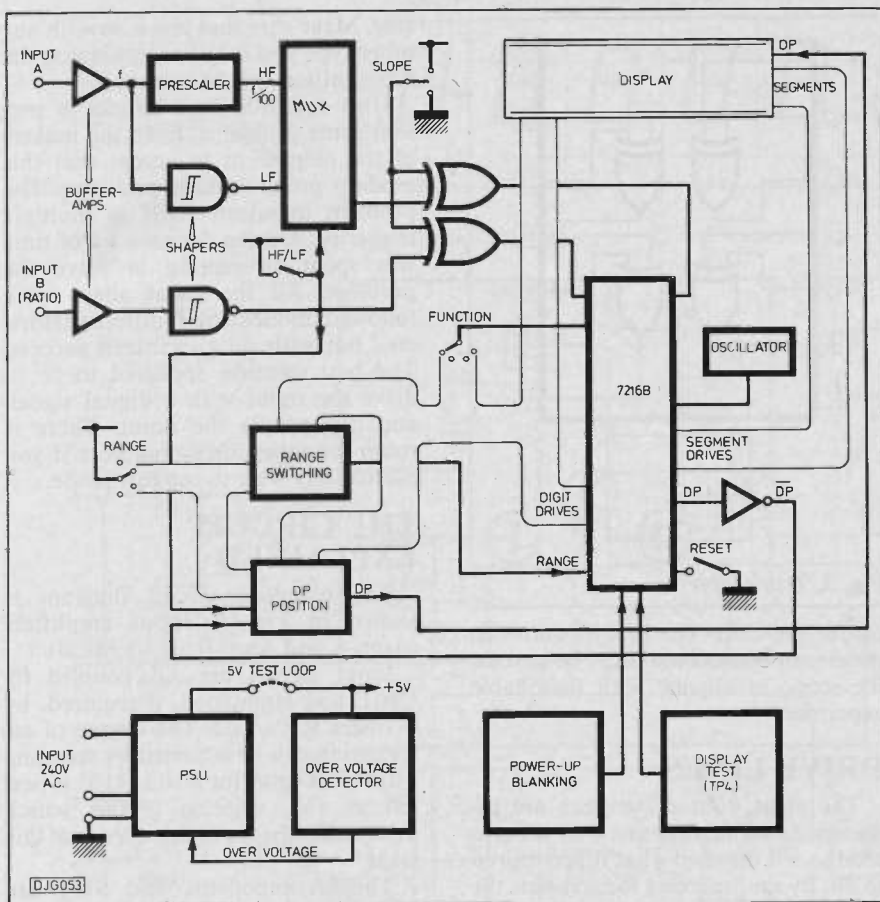**Photo 1.** *Internal and external construction*

Fig. 1. *Block diagram of the Multifunction Counter*

were convinced they were put on earth as mini VHF oscillators!

The trade-off is that decimal point driving is that little bit more involved, since in HF a shift of two digits right is necessary.

Both the LF and HF signals are then taken to a multiplexer chip, so that either may be selected by the Function switch. From the multiplexer the signal passes to an EXOR gate.

The maximum frequency at this point will be approximately 10MHz. Using an EXOR gate here is a simple way of inverting or not inverting the signal to the 7216, which always counts on falling edges. This allows the 'best' edge to be selected, so that a stable readout is obtained. It is worth noting that the 'minimum' sine input to the prescaler is 10MHz. Attempting to drive anything slower into it, or at least out of it, will give some strange results. It can, though, be driven right down to d.c., provided the slew-rate is not less than 50V/μs.

When the prescaler is left open-circuit it does have a tendency to pick up noise from the TTL chips and the 7216. This is normal, and if it should prove annoying either select LF, or change the value of a resistor. It was found by trial and error that the optimum value for pick-up and that for sensitivity were exactly opposed, so we are left with another compromise.

It should also be said that at no time during testing did this pick-up affect the results.

As can be seen from Fig. 1, the B-input passes through a Schmitt also, but then goes straight to the EXOR, before going to the 7216.

SWITCHING

From just a glance at the block diagram it should be fairly evident that some involved switching is needed.

Dismissing the easiest ones first, Input Attenuation, Slope and Reset switches are all p.c.b. mounting single pole types. Mains supply is not too taxing to sort out either, being a double pole switch, mounted on the rear panel.

Both Range and Function switching is done using rotary types. Range uses a 1-pole, 12-way, and Function uses a 2-pole, 6-way.

The counter chip is controlled by particular 'digit drive' lines being applied to some of its input pins. What it then does is to sense which of these lines has been applied, and from this, decide which range, function and control mode is required.

Function switching, HF, LF, Period, Ratio and Unit, is done in exactly this way. HF and LF, as far as the chip is concerned, are identical, i.e. both are frequency. However, when changing

from LF to HF several things must be done. First, the counter must be told to work in frequency, the correct output from the multiplexer has to be sent to the EXOR and, third, the d.p. position must be shifted. These tasks are made easy by using part of the function switch as a d.c. input to logic gates, and doing the 'digit drive' encoding in this way.

Range switching is completely digital. Since the same 'digit drive' lines are required for both d.p. and range switching, this seemed quite an elegant solution.

Although not a part of the switching process as far as the user is concerned, there is another input, 'control', on the counter. Part of a power-up test is done using this input. When power is first applied to the circuit it will be seen that the display remains blank for a couple of seconds. This is done for two reasons. Firstly, it gives the power supply time to stabilise, reducing the initial surge, and secondly it gives the user time to check that no segments or complete digits are permanently on.

Another part of this test is available at a test point. When this point is connected to 'control' it enables all the displays to show 8's. This is dealt with in the section on setting up and testing.

So to summarise, the easiest and cheapest way has been taken wherever possible. Hopefully all will be revealed and clarified when the circuit proper is discussed.

DISPLAY

The display used in the prototype is a 0·5 inch, common cathode l.e.d., with right hand d.p. Only this type is satisfactory. The chip contains its own drivers, but as they can only source a maximum of 12mA, good quality displays are recommended.

Display contrast can be considerably enhanced with the addition of some polarising material. As with most good ideas, it was found to be a very difficult material to obtain. It is available from a few trade-only suppliers, but tends to be quite pricey. A reasonable solution is to fit a piece of Perspex or similar material. If you shop around it is possible to get fairly thin (2mm) red plastic which works very well.

Both the cathodes and the segments are driven directly by the counter. Because of the need to shift their position, the d.p.s are further processed before being taken to the display.

THE ICM7216B UNIVERSAL COUNTER CHIP

The Intersil ICM7216 comes in four very different types. *It is most important that only the type—suffix B is used*

in this design. Types —A, —C and —D are not suitable. The ICM7216B is a 10MHz universal counter with an on-chip 8-decade data counter and latches, decoder, multiplexer and digit driver.

It can function as a frequency, period, ratio and unit counter. There is also a function measuring time-interval, but this is not used in this design.

In frequency mode gate accumulation times of 0·01, 0·1, 1 and 10 seconds are selectable. With a gate time of 10 seconds the counter can resolve to 0·1Hz. There is 0·2s between successive measurements in all ranges, and frequency is displayed in KHz regardless of gate time. In period the time is displayed in microseconds.

Leading zero suppression and overflow indication is included, although it is possible for up to two zeros to appear in front of the d.p. when using the prescaler. The display is multiplexed at 500Hz. The duty cycle for each digit being 12½%. In order to avoid ghosting (one digit 'smearing' into the next), there is a 6μsec blanking period between digits.

Peak segment current is 12mA, so high efficiency displays should be used.

There is an on-chip oscillator, which requires a 10MHz crystal, a high value resistor (10–20M), a trimmer and a capacitor. It is also possible to use an external oscillator, although this is not included in this design. Anyone wishing to use this facility is advised to obtain a full data sheet when sending
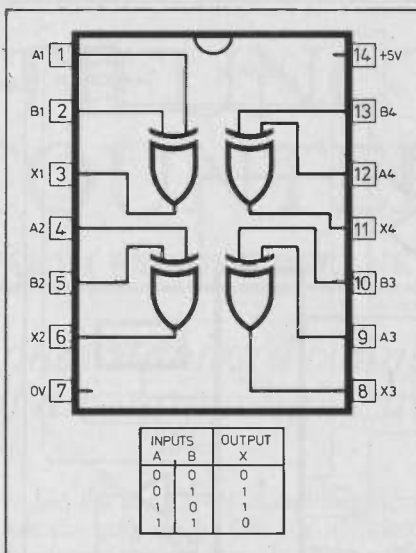
Fig. 3. *Truth table*

off for the chip. The modifications to the circuit board should not be beyond the scope of anyone with reasonable experience.

DRIVE LINES

The eight digit drive lines are bi-directional. That is to say, they are also used to tell the chip what it is required to do. By multiplexing these inputs the chip knows what state the 'function', 'range' and 'control' lines are in. This makes for a much simplified switching arrangement.

Two signal inputs are provided, 'A' and 'B'. These are both digital inputs, and it is important that the voltage applied to either does not exceed V+ by more than 0·3V. Doing so will almost certainly destroy the device (not to mention your bank balance!).

In order to avoid possibly damaging the chip some sort of buffer-amp is required between the input (raw) signal and the counter.

Input-A has a maximum input frequency of 10MHz. The chip uses this input for all counting functions except ratio. When in 'ratio' function both A and B inputs are measured. The counter then calculates fA/fB, and displays the result. By adding a prescaler after the input amp it is possible to measure frequencies greater than 10MHz. Input-B fmax is quoted as 2MHz, although the unit has been used to successfully measure up to 2·7MHz.

The counter advances on negative-going edges in all modes. There is also included a 'reset' input. When taken low the internal counters and latches are set to all zeros.

Extra circuitry is required to control the position of the d.p.s when using a prescaler. It is necessary to drive them externally, which happens to fall nicely in with the plans to use cheap and simple switches. This design uses displays with the d.p. on the right hand

side. Make sure that this is so with any other type you may use, otherwise the d.p. position will be incorrect.

Unit counting does appear to present some problems. Even the makers of the chip seem to accept that this mode is prone to noise problems. The problem manifests itself as multiple triggering. During design a lot of time was spent attempting to solve the problem. All the usual alleys were followed; monostables, differentiators, etc., but with no guaranteed success. The best solution appeared to be to drive the input with a digital signal, and d.c. couple the input. There is room for experimentation here if you particularly wish to use this mode.

THE CIRCUIT EXPLAINED

The complete circuit diagram is shown in Fig. 4. Input amplifiers (Amp-A and Amp-B are identical).

Input signals are a.c. coupled by C101, and attenuated, if required, by dividers R101/102. The degree of attenuation can be adjusted by selecting a different value for R102. R101 is best left at 1M, since it is this which determines the input impedance of this stage.

These components and S101 are mounted on the display p.c.b., and the signal is coupled to the rest of the circuit with screened cable.

R3, D3 and D4 are protection devices, limiting any input to TR1 to a maximum of ±0·6V.

The d.c. supply to both 'A' and 'B' amps is filtered and decoupled by L1 and C12. Further smoothing is then done with R31/C47 and R32/C207 respectively. All this filtering is necessary to reduce the effect of multiplexer-induced gliches on the input. After filtering, the maximum peak-to-peak noise seen on TP1 should not exceed 5mV.

TR1 and TR2 form a super source-follower. The d.c. operating point of this stage is set up by VR1, which also sets the switching threshold of the following stages, and is adjusted to give maximum sensitivity.

TR3 further amplifies the signal, which is then buffered by emitter-follower TR4.

The value of C8, a 10μ tantalum, may be changed if desired to suit individual needs. The value chosen is a good all round one, but if a lot of low-frequency measurements are to be made, increasing it will give better results.

The output from TR4 is simultaneously applied to IC4a and IC2. IC4 is a 74LS132 NAND Schmitt. By adjusting VR1 the point on the input signal at which this triggers can be varied. Best results were obtained when the d.c. voltage at TP1 was set to
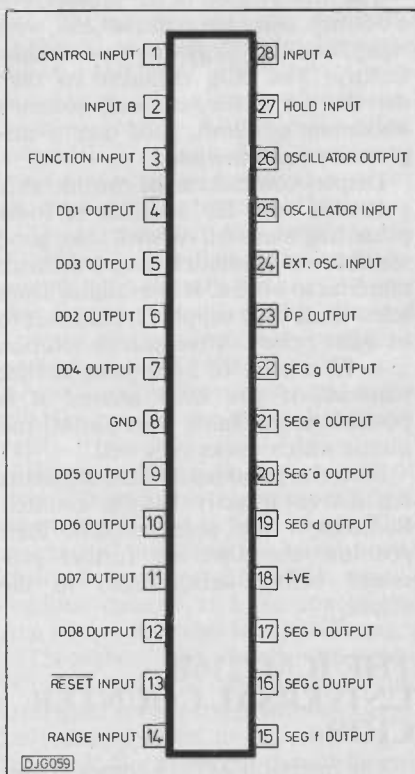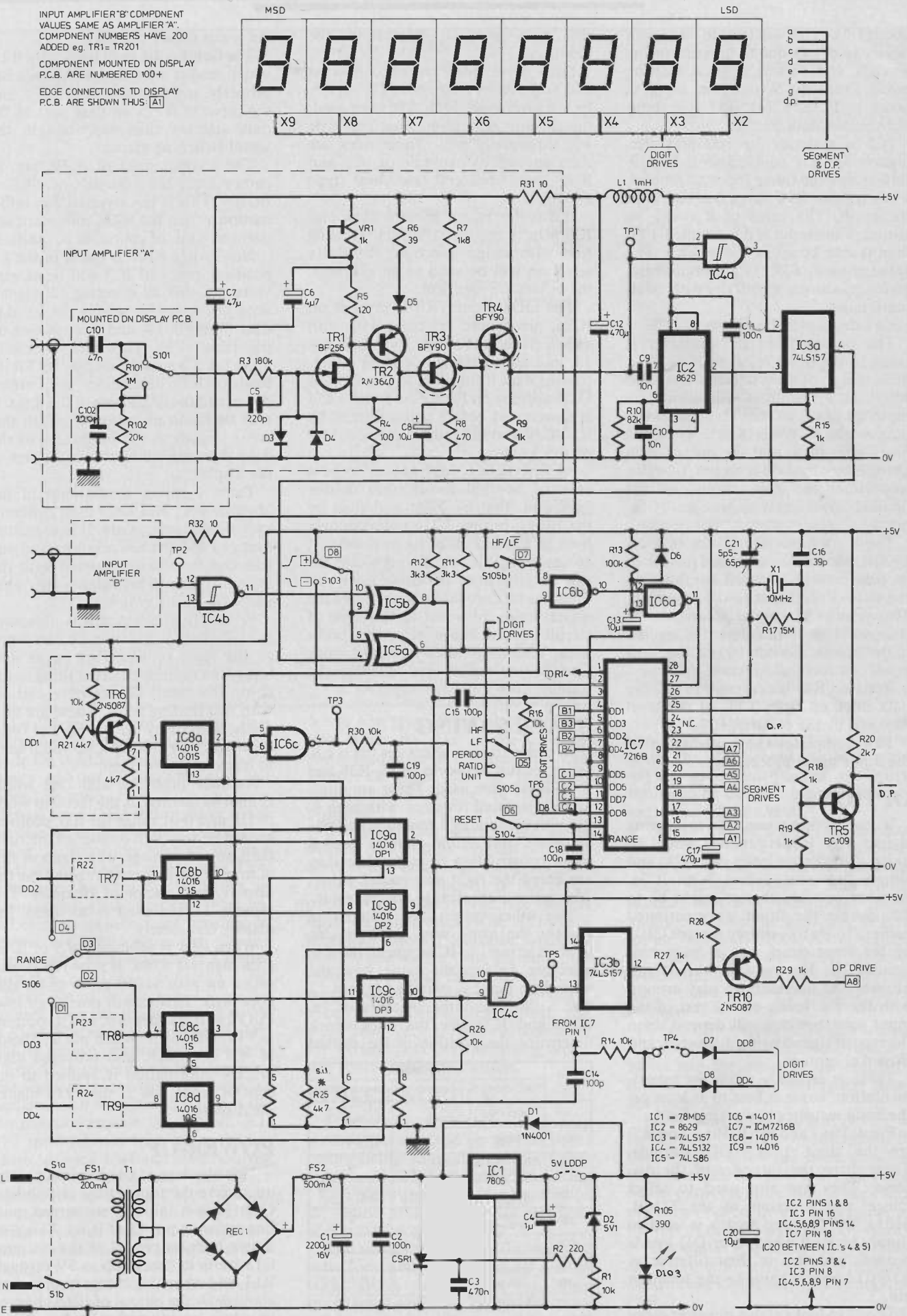

Fig. 2. *7216B pin-out*

Fig. 4. *Complete circuit diagram of the Multifunction Counter*

about 1·5V. This will tend to vary from device to device due to manufacturing spreads, but this is a good starting point. From the Schmitt the signal is taken to IC3a, a 74LS157 two input multiplexer/data selector.

IC2 is a divide by 100 prescaler. Signals are a.c. coupled to it by C9. C10 straps the other input to ground, while resistor R10 puts a d.c. bias onto its inputs. The value of R10 can be varied, if the input is d.c. coupled TTL then it may be set as low as 6K8. The value chosen, 82K, is a compromise, giving maximum sensitivity with minimum noise.

C11 decouples the supply to IC2.

The output from the prescaler is taken to the other input of IC3a. R15 pulls pin 1 of this selector low, and when in this state it will allow any input on pin 2 to pass through to the output pin 4. When S105b is closed pin 1 goes high, and the output then changes to whatever is on pin 3. In this way either the direct input, or the divided-down input appears on IC5a, pin 4.

The truth table (Fig. 3) for IC5, an EXOR, shows how an input on one of its pins may be inverted by changing the state of the input to the other pin. This enables the signal polarity to be changed if required before it is applied to the counter. Switch 103 on the front panel controls this function.

Resistor, R11 is necessary to pull the data lines up from TTL to the level required by the counter, IC7.

This completes the explanation of the input signal processing.

OPTIONS

If you have no need for measuring signals over 10MHz then it would be quite in order to leave out IC2, and simply link pins 2 and 3 on IC3a. Another possible change might be to d.c. couple the input, as mentioned earlier. To do this simply replace C101 on the front panel with a resistor of around 2K. Having done this it will probably be necessary to play around with the d.c. levels on the rest of the input amp, but this will depend upon the type of signals being measured, and their d.c. content.

There is certainly room for experimentation, but it is best to at least get the basic instrument working first!

Pin 4–Pin 7 and Pin 9–Pin 12 on IC7 are the 'digit drive' (DD) outputs. These drive the cathodes of the displays. They are also used to select 'range' and 'function' by the 7216B. S105a, the function switch is used to simply pick off which ever DD line is needed, and this is then filtered by R16/C15 before going to the function pin, 3.

The 7216 looks at this pin after every DD period, and depending upon when

this goes low, it determines the function.

Digit drive lines are also inverted and buffered by transistors TR6–TR9. In the prototype, 2N5087s were used, though any general-purpose *pnp* type will do equally well. These lines are then applied to one side of IC8 and IC9, quad bilateral switches (type 14016).

IC8 is the 'range' selector chip, and IC9 selects the d.p. position. Dealing first with range selection, the 0·01s selection will be used as an example, the others are identical.

The $\overline{DD1}$ from TR6 is present on IC8a, pin 1, and selecting 0·01 with switch S106 puts a high level onto pin 13, and the switch inside IC8a closes, passing data from pin 1 to pin 2. Thus $\overline{DD1}$ appears on IC6c pins 5 and 6 and is re-inverted before being filtered by R30/C19 and the input to the counter on pin 14.

At first sight it may appear to be a case of overkill to do this double inversion, first by TR6, and then by the 14011, but the 7216 unfortunately lives in a world all of its own when it comes to logic levels! Trying to use the raw outputs from the drive lines was found to be unreliable. Sometimes the digital noise inherrent in this type of circuit would cause selection problems, and sometimes it would work fine. So the mallet was taken to the walnut!

SPACE SAVING

In order to save space on the p.c.b. some resistor networks (R33–R39 and R40–R46) were used. These are miniature integrated resistors, with each 8-pin unit containing 7 resistors, and one common connection. Care is needed when constructing to make sure they are fitted the right way round, otherwise some quite strange effects result.

The other ranges are selected in exactly the same way. $\overline{DD1}$ is also applied to pin 1 of IC9a, one of the d.p. selectors. In just the same way, the ouput on pin 2 is switched by pin 13 and S106. The three switches, IC9a, IC9b and IC9c are the ones which determine the position of the shifted

d.p.s, not the LF positions.

The outputs are then loaded by R25, which makes sure that IC4c switches properly, and then appears at TP5, and the input of IC3b, another part of the data selector chip described in the signal switching above.

The second input of IC3b, pin 14 comes from the collector of TR5, a BC109. This is the inverted d.p. information which the 7216 automatically outputs. This, of course, is not shifted.

Now, when S105 is open, in the LF position, pin 1 of IC3 will be at zero volts. As well as selecting LF signals onto pin 4, it also selects the LF d.p. data from pin 14, and this appears on pin 12 of IC3b. This data is used to drive the d.p.s on the display by TR10. Resistor R29 determines the current drive, and the brightness of the d.p.s. It may be found necessary to adjust this value slightly if the brightness of the d.p.s does not quite match the rest of the display.

Table 1 shows a summary of the 'digit drives', and what their different switching functions are. It is suggested that you spend a few minutes studying this and familiarise yourself with the system. This will help clarify the 'what and why' of the switches.

When HF is selected it is necessary to shift the d.p. position by two digits to the right (/100). This is, as described, an entirely external thing to the chip. The result of this is to end up with two leading zeros. These are normally blanked by the 7216B, but there is no easy way around it, so you'll have to learn to ignore them!

Another problem, and one which cannot be ignored, is the fact that when in HF and 0·01 range the d.p. position should be one digit further to the right than we can manage. The result of this is to give an incorrect reading on the display, by a factor of 10 times. The remedy I have used is to blank the display completely.

When 0·01 is selected pin 9 of IC6b goes high via S106. If now HF is also called up with S105b pin 8 of 6b also goes high. This makes pin 10 go low. Pin 12 of IC6a goes low, and its output, pin 11, goes high. When pin 27 (hold) of IC7 goes high, and provided digit drive-4 information is applied to the control input, pin 1, the 7216 blanks the display.

POWER-UP

This blanking is also used on power-up, to give the supply time to stabilise. C13 (10μ) is initially uncharged, putting a low on pin 13 of IC6a. This also puts a high on pin 27 of the counter. C13 starts to charge up to 5V through R13, and when this charge has reached about 3·5V the output of IC6a changes to a low, enabling the display. When power is removed from the instrument

DIGIT DRIVE OUTPUT	7216B INPUT		
	FUNCTION(PIN 3)	RANGE(PIN14)	CONTROL (PIN 1)
DD1	FREQUENCY	0·01 SEC/ 1 CYCLE	EXT. OSC. * ENABLE
DD2	RATIO	0·1 SEC/ 10 CYCLES	1MHz * SELECT
DD3	OSCILLATOR * FREQUENCY	1 SEC/ 100 CYCLES	•
DD4	UNIT COUNT	10 SEC/ 1000 CYCLES	DISPLAY BLANK (WITH HOLD)
DD5	TIME * INTERVAL	•	•
DD6		•	•
DD7		•	•
DD8	PERIOD	•	DISPLAY TEST (ALL 8's)
* = FACILITY NOT USED • = NO FACILITY ON 7216B			

Table 1. *DD-Line functions*

MULTIFUNCTION COUNTER

COMPONENTS . . .

RESISTORS

R1,R14, R16,R26, R30	10k (5 off)
R2	220
R3,R203	180k (2 off)
R4,R204	100 (2 off)
R5,R205	120 (2 off)
R6,R206	39 (2 off)
R7,R207	1k8 (2 off)
R8,R208	470 (2 off)
R9,R15,	1k (8 off)
R18,R19, R27,R28, R209	* See text / All resistors ½W 5%
R10	82k
R11,R12	3k3 (2 off)
R13	100k
R17	15M*
R20	2k7
R21–R25	4k7 (5 off)
R29	47
R31,R32	10 (2 off)
R101, R103	1M* (2 off)
R102, R104	20k* (2 off)
R105	390
R33–R39	10k 7-element with common s.i.l.
R40–R46	4k7 7-element with common s.i.l.
VR1,VR2	1k cermet (2 off)
L1	1mH*

CAPACITORS

C1	2200µ 16V min. single ended
C2,C11, C18	100n ceramic (3 off)
C3	470n poly layer
C4	1µ 10V tant.
C5,C205	220p polystyrene (2 off)
C6,C206	4µ7 10V tant. (2 off)
C7,C207	47µ 10V tant. (2 off)
C8,C13, C20,C208	10µ 10V tant. (4 off)
C9,C10	10n ceramic (2 off)
C12,C17	470µ 10V min. single ended (2 off)
C14,C15, C19	100p ceramic (3 off)
C16	39p mica
C101, C103	47n metal polyester (2 off)
C102, C104	22p polystyrene (2 off)
C21	5·5p–65p trimmer

SEMICONDUCTORS

TR1, TR201	BF256A f.e.t. (2 off)
TR2, TR202	2N3640 (2 off)
TR3,TR4, TR203, TR204	BFY90 (4 off)
TR5	BC109
TR6– TR10	2N5087 (5 off)
CSR1	TIC106 4 amp

REC	W005 1·5 amp
D101	Red 3mm
D1	BY126
D2	5V1/500mW
D3–D8, D203–D205	1N4148 or 914 (8 off)
D103	l.e.d.
X2–X9	TIL730(H) display (8 off)
X1	10MHz crystal
IC1	78MO5
IC2	SP8629
IC3	74LS157
IC4	74LS132
IC5	74LS86
IC6	14011
IC7	ICM7216B
IC8,IC9	14016 (2 off)

MISCELLANEOUS

T1 Drake PO609, 6VA p.c.b. mounting; IEC mains socket (fused); mains switch d.p.s.t. 250V 2A; S101, S102, S103 s.p.c.o. vertical, p.c.b. mounting; S104 s.p.c.o. momentary; S105 2-pole 6-way rotary; S106 1-pole 12-way rotary; heatsink; i.c. sockets, 14-pin (5 off), 16-pin (1 off), 28-pin; fuse clips (2 off); track pins; fuses, 200mA, 500mA, both 20mm; BNC panel mounting sockets (2 off); screened RF cable; case to fit; front and rear panels, to suit; p.c.b. mounting screws, washers, etc. (P.c.b. to be in *PE* PCB Service—next month.)

C13 will retain some of its charge. This charge would possibly damage IC6, so diode D6 is added to clamp C13 to the supply line so it discharges as the supply collapses.

Apart from DD4 information, DD8 can also be applied to the Control pin. Doing so turns the display on and holds all 8's. This is done using TP4. After assembly this link is fitted, to establish that all the digits are working, and that no segments are missing. In normal use TP4 loop is cut. On the circuit DD8 data is taken to Control through Diode D7.

Reset input is on pin 13 of the counter. This is a simple closure to 0V by S104. The reset line is decoupled by C18, to prevent incorrect triggering.

The 7216 contains all the components necessary to provide a high quality oscillator. All we have to add are the components around the crystal, X1. R17 must have a high value, somewhere between 10M and 20M. During development, some time was spent experimenting with different values for this resistor, but with little effect. These tests, as indeed all frequency tests, were carried out using an off-air standard.

X1 is an HC18U-cased 10MHz crystal, although the p.c.b. is designed to take the larger HC33U style as well. Trimmer capacitor, C21 is a miniature 5·5 to 65p type. Again, the p.c.b. will take either the min. or the sub-min. two-legged style of construction here. Choose a good quality, preferably silver-mica, capacitor in the C16 position.

It might be that many purists would dismiss the simple crystal oscillator used in this design, as being 'intrinsically unstable', since it is not in an oven. Whilst this is true, the field is open to experiment. The 7216 will accept an external oscillator input, on pin 24, and with a little external programming plus an input socket on the rear panel, the counter may perform even better than at present. But, you must have very special requirements for accuracy before departing upon this course could be justified.

POWER SUPPLY

The mains input to the power supply is fused and switched on the rear panel before being connected to the transformer, T1. This is a p.c.b. mounting 6VA type with a secondary giving in the region of 12V d.c. after rectification and smoothing.

REC is a small p.c.b. mounting type, with a capability of handling a constant 0·5A without stress. The smoothed d.c. is applied to IC1, a 7805 regulator chip, well-known and equally well loved by all! The output from the regulator is decoupled by C4, and then connected to the circuit with a wire loop. The idea behind this is to allow any necessary fault-finding, and initial testing to be done without any danger to the rest of the circuit.

The 5V output is also connected to Zener diode, D2. This is a 5·1V, 400mW device, which samples the output voltage. If the 5V line should exceed about 5·5V, the voltage on the anode of D2 will be sufficient to turn on the thyristor, CSR1. R1 references the output from the Zener back to ground, R2 limits the gate current into the thyristor, and C3 prevents it firing on noise.

When CSR1 turns on, which it does in a matter of microseconds, fuse, F2, blows and the input to the regulator goes to 0V, thus preventing any damage to the i.c.s.

D1 is quite an important device in this circuit. Consider what happens to the regulator a few ms. after the CSR has turned on. Its input is at zero volts, but its output is at 5V, due to the effect of charge stored in the decouplers in the rest of the circuit. This very neatly reverse-biases it, and may in fact damage it. D1, however, by-passes it, allowing the caps to discharge safely into the CSR.

Next month: Further construction details, testing and operation.

BETTER USE OF DRY BATTERIES

PART 1 BY R. COOPER

How would you like a ten-fold saving on the cost of dry batteries? Read on...

OPERATION from dry batteries has a lot in its favour for home-constructed electronic projects. It's very safe—much safer than using the mains —and of course it makes the instrument portable. But no-one needs to be told that dry batteries are expensive, and are likely to become even more expensive as the raw materials slowly become scarcer. It is an unfortunate fact that most project designers simply tack on a battery (usually a PP3 or PP9) at the end of a project almost as an afterthought, with no regard for how much the circuit is going to cost to run. This often results in a project which costs far more to keep running than it did to build in the first place.

NICADS

To counteract this problem, many constructors have turned to sealed (Nickel-Cadmium) batteries as a possible cost-effective alternative to the dry battery, as in theory they can be recharged 500 times. However, sealed NiCad batteries have many hidden snags; who hasn't had his fingers burned with an expensive but troublesome NiCad battery?

Probably the biggest snag with the NiCad of the sealed sintered type is the way in which it discharges itself on standing. You can leave a piece of equipment on the bench for a few weeks, and when you come to use it, the NiCad battery is flat, through self-discharge. This can be very irritating! Typically a "D" size NiCad cell will lose about 40% of its charge in just 40 days when brand-new, and worse than this as it gets older.

Besides being expensive to buy, Ni-Cads need recharging gear. This can be expensive if it is designed to do the job properly, but most of the cheap, simple chargers are very unsatisfactory. There are many failure modes which will prevent the NiCad battery from reaching 500 charges that it is supposed to achieve. (See Part 2 next month.)

Also, the capacity of NiCad batteries is much less than that of equivalent dry cells. Imagine that you are a member of a mountain rescue team carrying a portable tranceiver powered by 6 Duracell "D" size cells, and that you have to carry this load to the top of a mountain. At a discharge current of 125mA you would get 70 hours of operation, assuming an end voltage of 1V per cell. With NiCad cells, you would need 7 or 8 cells to get the same voltage, and they would last only 30 hours. You would be required to carry between 16 and 19 NiCad cells to achieve the same operating duration, and to add insult to injury you would find that each NiCad cell was 25% heavier than its Duracell equivalent. Which would you prefer?

For these reasons there may be something of a return to using dry batteries for many applications, particularly when their potential for being recharged is realised. For example, I used to have a handlamp powered by six NiCad cells until I became fed up with its continually going flat due to self-discharge, the occasional leakage of electrolyte, the persistent failure of individual cells in the battery and short endurance even when fully charged. It is now powered by alkaline-manganese cells (Duracell) dry cells, but these are used in a far more effective way than previously—they are recharged using the Periodic Current Reversal technique, a safe way of recharging dry cells up to 20 times that will be described in part 2 next month. In addition to recharging, there is another, relatively new technique which dramatically reduces running costs and which is making considerable impact. Its main use is in light loads taking up to 100mA, such as electronic circuits running off small 9V dry batteries, and is described below.

SAVING MONEY ON LAYER BATTERIES

Dry batteries are superior to NiCads regarding charge-retention and reliability, and the much greater capacity and lighter weight of alkaline-manganese types gives them a definite edge over NiCads, but all dry batteries of the layer type like PP3 are expensive.

One way of retaining the better qualities of dry cells but reducing the cost is to use a d.c./d.c. converter working from a single cell, like the Verkon V6. The difference in cost per unit of available energy between PP3-type batteries and single cells is astonishing, as Table 1 shows.

Hence the saving using the Verkon V6 instead of the PP3 is £4.19 less 89p = £3.20. It may seem strange to pocket a saving of £3.20 every time you change the cell in a d.c./d.c. converter system, but there you are! Of course, the cost of the converter has to be taken into account (£5.50 in this example) but this will clearly be repaid within the first two cell changes. Note that in the example, the voltage output from both cell and battery was taken as 1·5V per cell, whereas in reality it drops below this on load. However, since the same assumption has been made in each case, it makes no difference to the result of the calculation.

Most circuits working from PP3, PP7, etc. will also work happily from an 8V d.c./d.c. converter like the V6—bear in mind that the end-point of a PP3 is usually taken as 6·6V and you will realise how voltage-tolerant battery-powered equipment has to be. Alternatively, there is another d.c./d.c. converter, the V12, with a 12V output
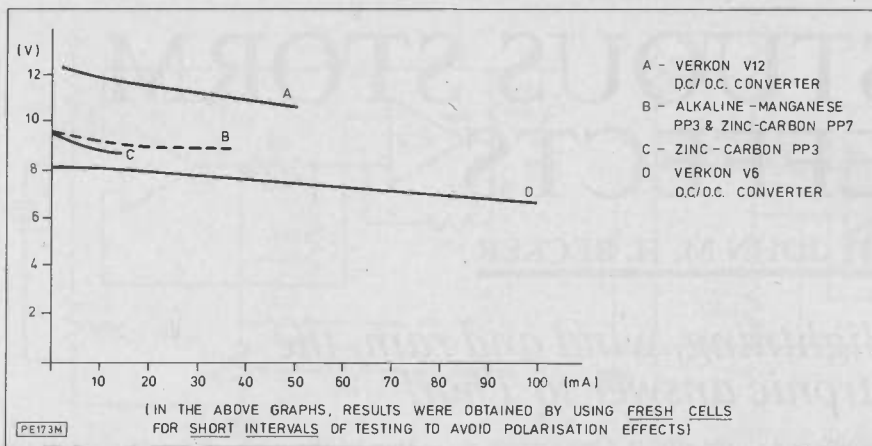
Table 1. *Energy costs per unit*

	PP3 (DURACELL)	D CELL (DURACELL)
COST TO BUY	£1.89	89p
CAPACITY IN AMP-HOURS	0·5	10
ENERGY CONTENT IN WATT-HOURS	4·5	15 (10 AFTER CONVERSION TO 8V)
COST FOR 10 WATT-HOURS OF OPERATION	£4.19	89p

Fig. 1. *Battery performance curves*

A – VERKON V12
    D.C./D.C. CONVERTER
B – ALKALINE-MANGANESE
    PP3 & ZINC-CARBON PP7
C – ZINC-CARBON PP3
D – VERKON V6
    D.C./D.C. CONVERTER

(IN THE ABOVE GRAPHS, RESULTS WERE OBTAINED BY USING FRESH CELLS FOR SHORT INTERVALS OF TESTING TO AVOID POLARISATION EFFECTS)

which can be stabilised at 9V with a 78LO9 voltage regulator. Performance curves of batteries and converters are shown in Fig. 1.

Alkaline-manganese cells and batteries were used in the costing example given because the alkaline-manganese D-cell is the preferred power source for the Verkon V6, but the same exercise can be done on costs for ordinary zinc-carbon cells and batteries with similar results. The Verkon converter will work with zinc-carbon cells, but as you would expect the performance is not as excellent as it is with alkaline-manganese.

To get the best out of the Verkon converter, some knowledge of how it works is essential, so here are a few practical notes for constructors.

USING VERKON D.C./D.C. CONVERTERS

The standard circuit is shown in Fig. 2. The converter, which occupies less than 1 cu.in., can easily be p.c.b. mounted, preferably in close proximity to the decoupling capacitors. C_{in} is 470μ 2·5V and C_{out} is 470μ 16V.
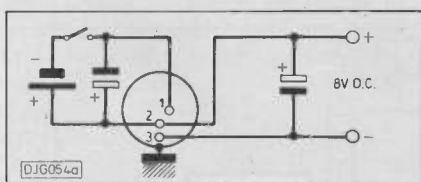
Fig. 2. *Standard circuit*

To achieve high conversion efficiency (typically over 70%) at such low starting voltages as 1·5V, the Verkon "V" range uses a variable-drive technique. That is to say, the power available to drive the power-switching transistors is increased as the load at the ouput is increased. It follows that when there is no load, there is no drive and the converter will be quiescent even though the input is supplied with power. Verkon converters need a small

load current to turn on and remain on, and the value of this current is about 1mA at the rated output voltage. Most load circuits—small motors, lamps, relays, etc.—will draw this current and turn the converter on the moment they are connected, but a few electronic
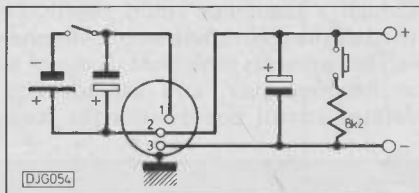
Fig. 3. *Continuous voltage*

load circuits will not do this. Some electronic circuits draw negligible current until a certain voltage is reached, because of the need to forward-bias the semiconductors before any appreciable current will flow. If a particular load circuit is unable to draw sufficient initial current, it can be assisted by putting a resistor across the output of the converter, so that 1mA flows.

This resistor may be switched out when the output voltage has been reached if the load circuit is then drawing more than 1mA, for example by using a push-button starting switch (Fig. 3). However, the simplest method is to leave this resistor permanently connected as the power used is only 10mW, and a more sophisticated arrangement is usually only justified when the power used by the load itself is very low, or in those applications where the absolute maximum endurance is wanted out of the cell.
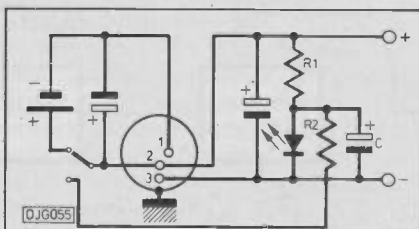
Fig. 4. *Positive turn-on*

One elegant and simple method of ensuring positive turn-on with very light loads is shown in Fig. 4, where a low-current l.e.d. is used as an indicator light to show the circuit is on. At switch-on 1mA to 2mA flows through R1 and C. The capacitor charges up to the working voltage of the l.e.d. (about 2V) and then the l.e.d. takes over. A low-current l.e.d. takes about 1·5mA. When switched off, capacitor C discharges through R2 and through the l.e.d. ready for the next time the converter is switched on.

If the converter is running under load and the load current falls below 1mA, the converter may well continue to run. In practice, stray current leakage at the full working voltage may be sufficient to drive the converter, although a higher voltage than that specified may appear at the output, or the voltage may ramp slowly up and down. This does no damage, but if the load circuit needs continuous voltage then the resistor of Fig. 3 should be made a permanent connection. This fact also means that the converter must be turned off with a switch in the input circuit as shown in Fig. 2, not with a switch in the output circuit. Verkon converters are very versatile and can be connected in parallel to give higher curent output (Fig. 5) or in series to give higher voltage. The higher voltage circuit can also provide a split rail supply of ±8V. The economies over using two PP3 or a vast string of NiCad button cells are enormous.
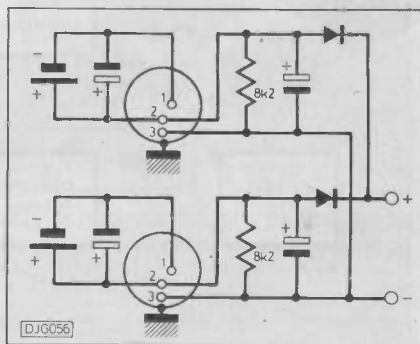
Fig. 5. *Parallel circuit*

Note that permanently-connected starting resistors are shown in Fig. 5. This is to ensure that both converters run at the same time, so that there is no chance that only one converter might take the full load while the other is quiescent.

In all these circuits, decoupling capacitors are required at input and output. Most converters, whether flyback, forward or push-pull, need these for stable operation, but the input capacitor can sometimes be reduced or omitted if space-saving is important provided that the input leads are very short and thick and there is no poor contact anywhere in the switch or cell-holder.
Next month: Charger construction.

TEMPESTUOUS STORM EFFECTS

BY JOHN M. H. BECKER

Thunder, lightning, wind and rain, the electronic answer to Thor!

THUNDER, lightning, wind and rain—the elemental rage of nature at its most powerful is an essential sound effect demanded by many dramatic films and plays. Professional film and theatrical producers have access to vast disco and tape sound effects libraries for these and other effects, but the amateur dramatist frequently has to resort to less conventional methods with varying degrees of success.

As in so many areas, electronics can offer an alternative solution, and this article describes two simple units for producing storm effects. One creates a variety of wind and rain sounds, with controllable tone, howl and sweep levels. Sea and surf sound can also be created with this module. The other creates the more dramatic effects of lightning crashes and rolling thunder, the levels and duration of which can be varied from panel controls. The triggering is via push buttons on the panel, though a computer could readily be used as the controlling source instead.

The two units have been designed as a matching pair, and use identical printed circuit boards with the function of the p.c.b. depending upon the component positionings and values. The output signals can be taken separately from both units direct to the normal high level inputs of an ordinary amplifier system. Alternatively the wind and rain module can be plugged into the thunder and lightning unit, and the composite mixed signal taken as a single line to the amplifier. Both will run from batteries or power supplies.

From the block diagrams it will be seen that in each unit there is a white noise generator, two controllable
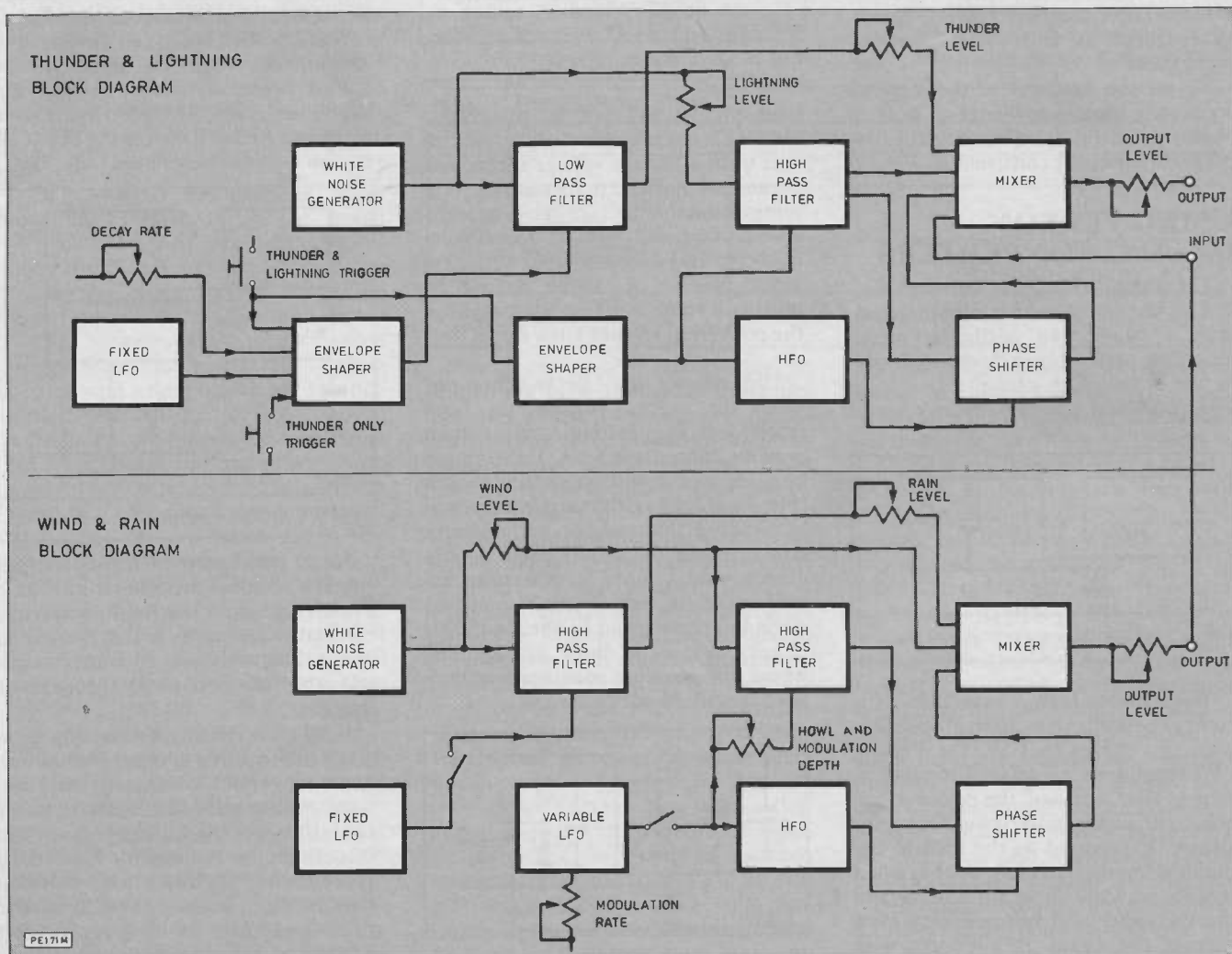
Fig. 1. *System block diagrams*
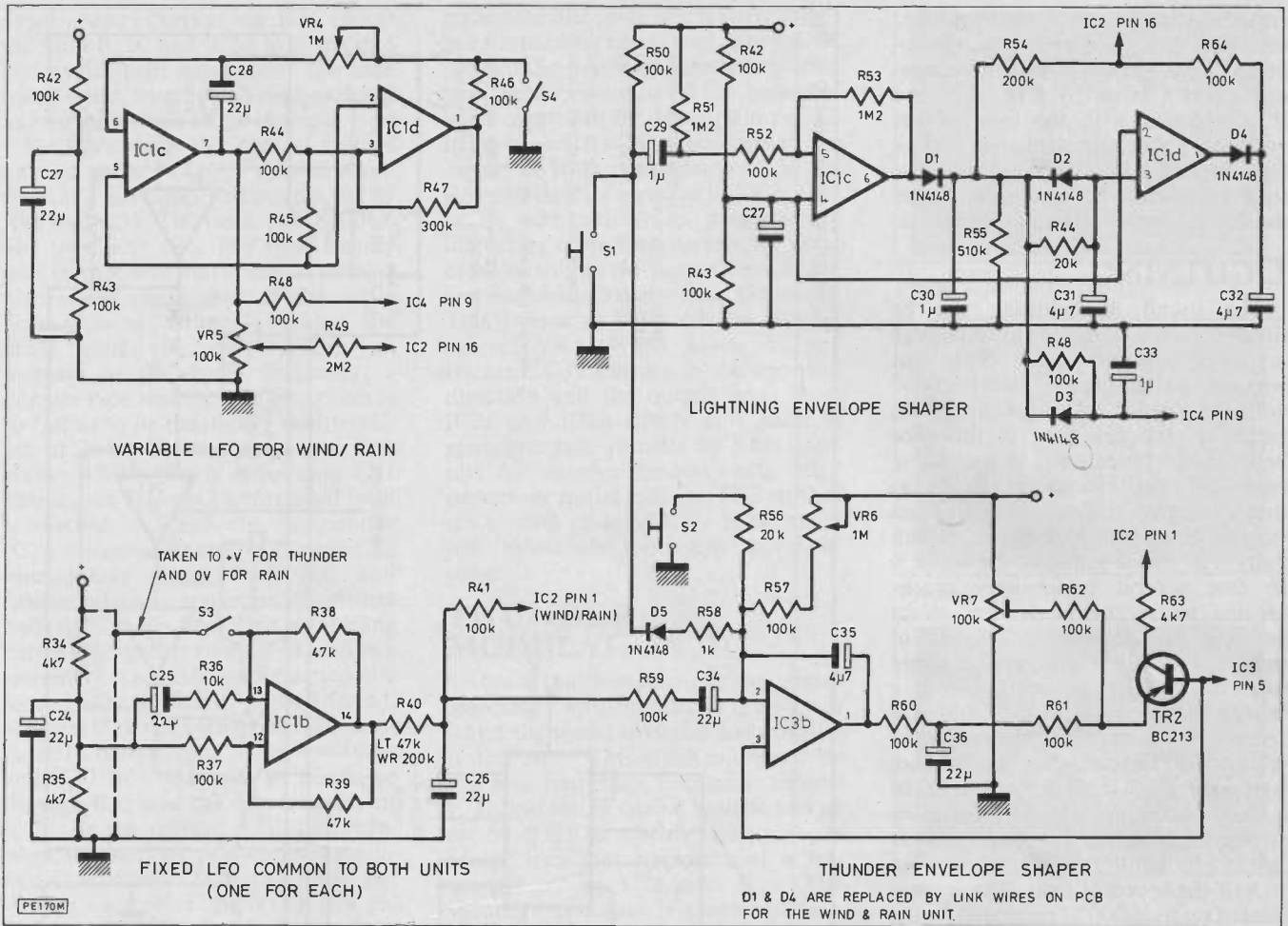
Fig. 2. *Signal processing circuits*

filters, a VCO controlled phase shifter and an output mixer. The basic difference between the units is the way in which the filters are controlled by their respective envelope shapers and modulation controls.

Any electronic component produces a certain amount of noise as electrons joggle around within it. Normally in any design the object is to minimise this noise level. For circuits like these here though, the object is maximise the noise output of part of the circuit and to manipulate it to create other sounds. Happily for these projects, reverse biasing of a transistor causes it to protest loudly, giving out white noise right across the audio spectrum, from very high to very low frequencies. By using a controlled frequency filter in the path of the noise, the desired frequency band can be selected.

Transistor TR1 produces around 50mV of white noise when using a BC549. Other *npn* transistors can be used instead, but the output noise level may vary between types and various production batches. IC1a then gives further amplification up to about 2 volts for 50mV fed in (Photo 1). On its own this level would be suitable for

feeding directly to an amplifier system as a reasonable simulation of heavy rain sounds, though without any frequency or amplitude correction and modulation.

The two networks around IC2a–IC2b, and IC2c–IC2d can function either as band pass filters, or voltage controlled amplifiers, or a mixture of both, depending upon the components used. Taking IC2a and b, the lowest frequency allowed in is set by C2, with a large value allowing more base frequencies to pass. C4 if used, pre-restricts some of the upper frequencies. C5 then further restricts them, depending upon its value and the current at the control node of IC2a. IC2b acts as a high impedance buffer and the feedback via R8 sets the tightness of the filter cut off level.

With R8 out of circuit and with R6 included, the network behaves with the characteristics of a VCA as well, the output level being varied by the control current. For the rain circuit, this network is used purely in its filter mode. For thunder production it is mainly the amplitude that is changed. The network around IC2c and IC2d is used simply as a filter.

For both the Lightning and the Wind creation circuits, the effect is enhanced

by phase shifting part of the signal, and recombining it with the unshifted one at the output mixer. The signal is fed in to IC5, which is a bucket brigade analogue delay line chip containing 512 stages. The audio signal is repeatedly sampled at its input, and each sample is progressively passed from one stage to the next in response to a bi-phase clocking signal.

The rate at which the samples emerge from the output is directly related to the frequency of the clocking signal, with a slower clock causing a longer delay between the shifting of each sample. The phase change occurs inevitably because of the delay. If this phase shifted signal is heard on its own, the shift will not be apparent, but if it is mixed with the original, amplitude cancellation will become progressively greater for respective parts of the signals the more their phases oppose each other.

By continuously changing the delay rate repeated enhancement and cancellation occurs. This is particularly noticable with spiky waveforms in the upper audio frequency range. Many musical effects units use this principle for creating the familiar Phasing effect so widely used.

The bi-phase clocking signal is gen-

erated by the linear voltage controlled oscillator IC4. This produces two opposing clock squarewaves, the frequency of which is set by C18, R21 and R22, together with the level of the voltage on the control pin. As will be seen shortly, this changes in response to a modulator or envelope shaper depending on the effect being created.

LIGHTNING

The sound of lightning can be likened to the noise of the discharge across a gigantic spark plug, but whereas perhaps only about 16000 volts are needed to bridge the 0·03in gap of a car spark plug, the distance between the "terminals" in a cloud to earth lightning discharge can be as much as a mile, and the voltage needed to cross between as high as 100 million volts. The initial sound of the strike is in fact several preliminary cracks created as successive leaders shoot outward each elongating the path of the previous one. They travel at a rate around 100 miles per second, over a period of about one hundredth of a second. When the leader is within the region of 50 feet or so from the ground, a streamer leaps from the ground to the leader, whereupon the main lightning stroke rages upwards, sometimes as fast as 87000 miles per second, or close to half the speed of light. The intense heat of up to 30000°C generated by the lightning stroke causes the air to expand with the violence of an explosion. The radiated shock wave travels supersonically but attenuates rapidly over distance, the higher frequencies dying faster than the slower ones. The typical crack of thunder is thus associated with strikes that are close to the listener, and the deeper noise of thunder is heard when the strike is further away. The prolonged rumbling of thunder happens both when numerous strikes occur in rapid succession within the storm area, and when turbulent conditions cause sound refraction and reflection within the cloud, as though the cloud were a giant echo chamber. In Britain thunder has been recorded lasting over twenty minutes, and considerably longer in tropical climates.

In this project several parameters are controlled in order to simulate the sound of the lightning strike, notably envelope shaping, filter variation and phase shifting. White noise is fed at a level set by VR2 to filter IC2c–IC2d. Until triggered, the output here is nil. Upon pressing S1 a negative going pulse is generated across C29, the duration of which is partly dependent upon the value of the capacitor and partly upon the time that the switch is held closed. The output of IC1c immediately swings from low to high, and remains so until C29 has recharged. C30 instantly charges via D1 and a

Fig. 3. Storm controller circuits
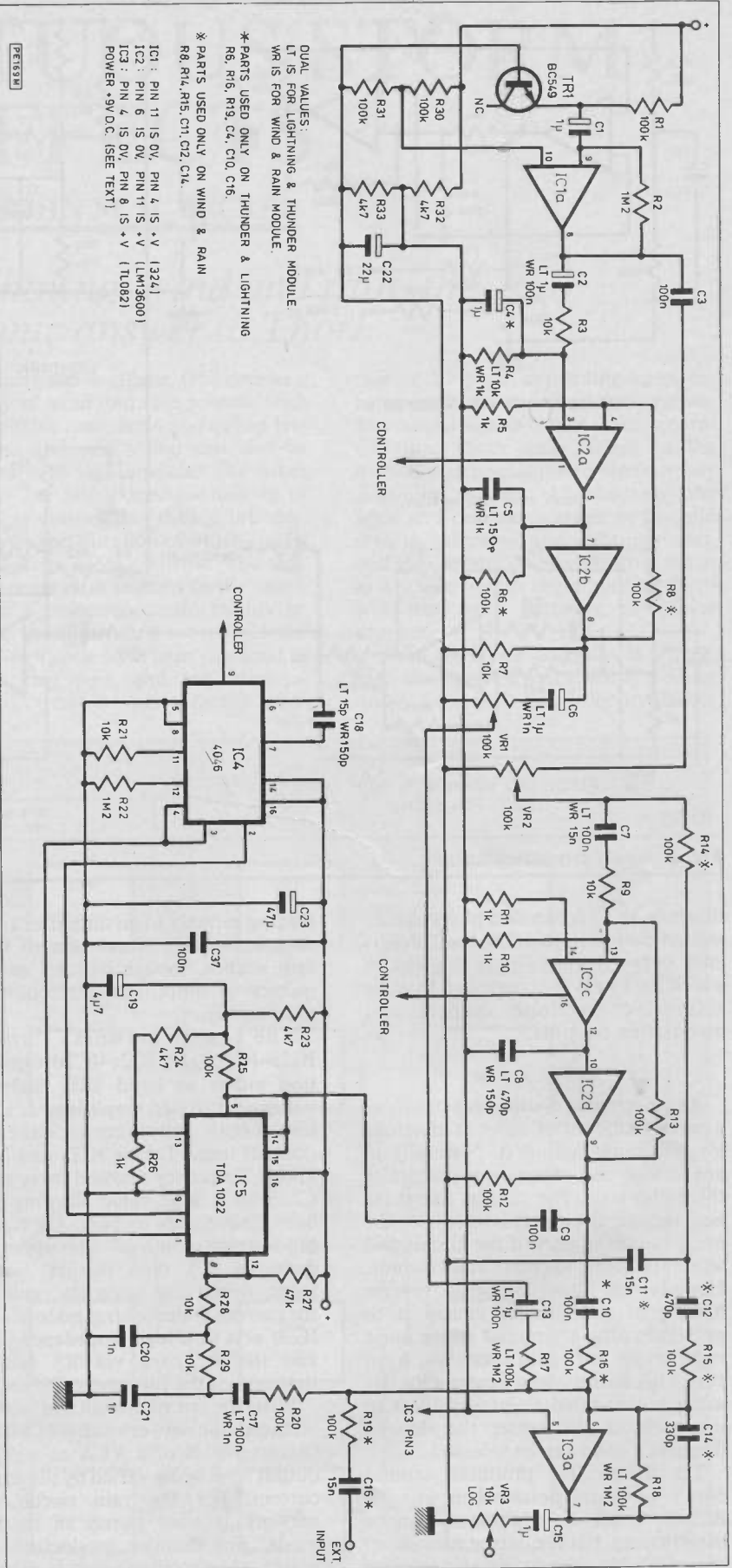
small control current via R54 causes the filter IC2C and IC2d to swing into almost full high pass mode. The high speed swing from low to high is heard as an initial crack at the output.

Simultaneously the control voltage applied to the VCO IC4 rises to maximum as a fast ramp, and at a rate set by R48 and C33. The clock rate controlling the delay chip IC5 thus rapidly goes from low to maximum, creating a high speed phase shift of the white noise passing through. Because the phase shift effectively creates an increase in the signal frequency, a doppler type shift occurs. The effect is so fast as to be practically subliminal, but it helps to emphasise the first crack. Whilst this is happening C31 charges via D2, until a threshold level is reached at which the comparator IC1d is tripped from low to high. C32 immediately charges via D4, and further current is applied to the control node of IC2c via R64. This controlling current is higher than the first, and so a secondary crack is heard a fraction of a second after the first. (Photos 5 and 6).

When C29 has recharged sufficiently, IC1c reverts back to its low state, and C30 to C33 begin to discharge through R55 and the control node of IC2c. As the current at IC2c diminishes, so the filter pass band is modified downwards. Simultaneously the voltage control of the VCO IC4 reduces, and the clock rate drops. As it falls the phase shift through IC5 expands accompanied by another doppler shift and reduction in the apparent output frequency. Since the outputs of the filter and phase shifter are mixed at IC3a, a greatly enhanced phasing effect is heard simulating the acute ripping sound of lightning as it shears between earth and sky. This is fairly brief and lasts for as long as the four capacitors remain charged above the minimum level needed by IC2c. As the charge falls to close to the minimum level, so the band pass frequency and level decays until it finally dies away completely. S1 is also coupled to the thunder generator and so the lightning sound can also be accompanied by rolling thunder, depending upon the setting of those controls.

THUNDER

The filter network around IC2a and IC2b is arranged so that this section acts both as a very low pass filter, and as a voltage controlled amplifier. C2 passes the low frequency content of the white noise signal, and C4 mops up most of the higher frequencies present. Further high frequency content is absorbed by C5. The amplitude control is then derived from the envelope shaper around IC3b. When either S1 or S2 are pressed, so C35 reverses its charge at a rate set by R56 or R58. For lightning

strikes the discharge rate is fairly rapid, but for thunder on its own, when S2 is pressed the discharge rate is slower so that the maximum level can be somewhat controlled by the duration of S2 being closed. As C35 discharges so the output of IC3b rises, charges C36 via R60 and applies a curent to TR2. This in its turn delivers a progressively increasing current to the control node of IC2a, so that the output level of the low frequency thunder rises. (Photo 4). This is sent to IC3a via the volume control VR1. When S1 or S2 are released, C35 charges in the opposite direction and the output level from IC2a and IC2b slowly falls back to zero, at a rate variable by VR6. This sets the thunder die-away rate. VR7 presets an initial bias on TR2 so that the control node of IC2a is normally just below its minimum threshold point.

THUNDER MODULATION

One of the characteristics sometimes associated with thunder is the way in which the sound swells up and down as it dies away. This effect is created by the low frequency oscillator around IC1b and which can be switched on or off by S3. The circuit is basically a square oscillator operating at a frequency set by C25 and R36. The squarewave output is smoothed to a rounder waveform by the inclusion of R40 and C26. With VR7 correctly set and the output of IC3b in its low state, the varying modulation current through C34 has no effect upon the VCA IC2a. However, when one of the pushbutton switches has been pressed and the output of IC3b is fairly well above its minimum, the modulation effect is apparent upon the relative thunder levels, recreating the swell and die repeats until C35 has discharged below the threshold level.

RAIN CONTROL

For the rain effect production IC2a and IC2b are connected as a high pass filter and are grossly over driven to emphasise the harshness of heavy rain. (Photo 2). The output level is panel controlled by VR1. To provide an element of variety into the rain sound, the filter band pass region can be varied by switching in the low frequency oscillator around IC1b. This is identical to the one used for thunder modulation except that the depth is slightly different and the control is a varying voltage via R41, whereas for thunder the control is a varying current via C34.

HOWLING WIND

It is interesting to speculate as to whether wind actually has a sound of its own. It seems probable that the

Photo 1. *Amplified filter noise*

Photo 2. *Rain*

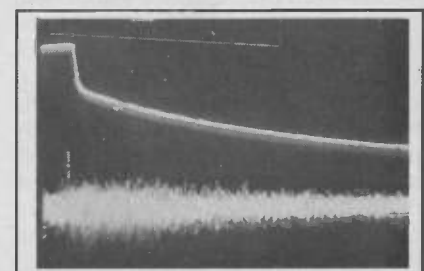Photo 3. *Wind*

Photo 4. *Thunder*

Photo 5. *Lightning*

Photo 6. *Lightning (spike)*

Fig. 4. *P.c.b.s and component layout details*

its tone and phase shifted with regard to the other, a howling effect is generated. (Photo 3). This is not a howl in the sense of that associated with microphonic feedback, but a howl as associated with wind careering round corners. The actual tone depends on how close the minimum voltage level is to the threshold point of IC2c. The nearer VR5 is to this point, so the wind note is deeper, and the modulation level lower. Because the primary white noise is subjectively louder in the upper frequencies, the wind amplitude level also decreases with the tone reduction. When VR5 goes below the threshold, filter modulation ceases but leaves the phase shifting in operation. With the modulation oscillator switched off, the twin path mixing allows for a constant wind sound, with the overall quality still variable by VR5. The majority of the wind level is controlled by VR2, with the residual controlled by VR3. Any of these panel controls can be varied manually at any time to create a wide variation of dramatic sounds, including sea and surf sounds at some settings.

OUTPUT STAGES

In both units, the mixing and output stage are to all intents identical. They both mix the relevant sound effect signals, pass them to a master volume output control VR3, and are suitable for feeding to a normal pre-amplifier or main amplifier system. The maximum voltage level swing is around 6 volts peak to peak, depending on the setting of the various volume controls. The lightning crash produces the highest output so that the emphasis is greater than with the other effects. On the wind and rain unit an additional feedback capacitor C14 is included to slightly further enhance the smoothness of the howling wind, but without significantly cutting the harshness of the rain. This capacitor is omitted from the thunder and lightning mixer as any top cut here would degrade the ripping quality of the lightning stroke. The additional input facility on this mixer is specifically so that the wind and rain can be brought in to this unit and a full composite fed to an amplifier as a single signal. It can be used for other external signals, though there is a deliberate restriction on lower frequencies due to the selected value of C16.

POWER SUPPLY

The units are basically designed for a 9V d.c. supply. The average current drawn by each is around 10mA, rising to about 15mA at peak settings. If the units are to be used for any great length of time on any occasion it is probably preferable to use long life high power batteries, or a battery eliminator. Al-

sound is mainly created when the wind comes into contact with something else, such as grass, trees, buildings, or just the ears of the listener. This is a difficult observation to test as even the presence of a microphone can create a surface upon which the moving air can have its sound producing effect. With the long directional microphones seen occasionally on television, the bulk of the what appears to be the microphone is in fact a wind baffle that helps keep the microphone responding only to the required sound source rather than to the wind. The actual microphone inside is usually a very slender tube only a fraction of the diameter of its shield.

Philosophical questions apart, to the listener wind does create a sound, and for a good storm sequence it has to be powerful. Characteristically it is usually portrayed as a howling wind, but it can equally well be constant blowing through trees without a particularly marked tonal variation. Four controls are designed into this section, these are modulation on and off, modulation rate, modulation and tonal depth, and volume control.

In the simplest form of electronic wind generator, the effect of varying

wind levels can be created by passing white noise through a filter, the band pass characteristics of which can be varied by a manual control. Manual control can also be used here, but the variation is mainly controlled by a slow oscillator around IC1c and IC1d. This produces a triangle wave output varying at a rate set by C28 and the resistance across the panel control VR4. It can also be switched off by S4. The varying output voltage is sent in two directions, firstly at a fixed level to the HFO IC4 via R48, and secondly at a level controllable by VR5 to the control node of IC2c. The voltage sweep from VR5 varies the frequency band pass window of the filter around IC2c and IC2d. The output from IC2d now goes to the phase shifting network of IC5.

Since the HFO IC4 is having its clock frequency varied by the voltage control from IC1c, so a second enhancement of the tonal variation occurs. In addition, the basic white noise is routed along a second path in which C11 takes out a lot of the upper frequencies and C12 restricts the lower ones. With these two signals combining at the mixer, and with one having

ternatively of course a conventional mains driven power supply can be used. Supply voltages greater than 9V may be used providing that R1 is increased. A suggested value for a 12V supply is 200k. Too low a value could cause IC1a to go into oscillation.

PCB ASSEMBLY

The two units use identical p.c.b.s, their function depending upon the component positions and their values. The two parts lists should be closely observed for which parts are used with each p.c.b. All the short wire links shown on the p.c.b. layout diagram should be inserted irrespective of the unit function. These can be made from resistor cut off leads. As usual, it is recommended that the p.c.b.s are assembled in order of component size as this makes assembly more methodical and easier to ensure that parts stay in their positions during soldering.

SOLDERING HINTS

Please pay the utmost attention to your soldering as this is probably the weak link if the unit fails to perform straight off. Work in a good light and ensure that the solder fully covers the component lead and the p.c.b. pad. Then check each join in close up with an eye level magnifier of at least ×6 magnification. These are available from opticians at very little cost. If part of the circuit fails to work as expected, go over the joins in the relevant area with the soldering iron again, just to make sure that they are adequately made. Sometimes scale can come off the soldering tip so impeding the quality of the join, and resoldering will probably overcome the problem. Ideally, you should of course keep the iron clean by wiping the tip with a damp sponge to prevent this. It is highly unlikely that if the components have come from a reliable source that they will be the cause of malfunction. However, if you have had the components in store for sometime, their leads may have partially oxidised, taking on a slightly dark appearance. This can hinder soldering. In these cases the leads can be scraped clean with a sharp blade before soldering. If the discoloration is only noticed after assembly, then the resoldering will allow the solder to take to the clean freshly trimmed end of the delinquent lead.

BOXING

The completed p.c.b.s each snuggly fit inside a 6in. × 4½in. × 1¾in. box. Mount them as far to the left and to the back as is possible. The potentiometer centres should be drilled 0·8 inches from the bottom and 1 inch apart. Allow 0·5 inches between the switches. Keep the wiring neat and take around the edges of the board to the controls, this makes the finished article look far more professional than if leads appear

COMPONENTS . . .
THUNDER AND LIGHTNING

RESISTORS

R1,R6, R12,R13, R16–R20, R25,R30, R31,R37, R41,R42, R48,R50, R52,R57, R59–R62, R64	100k (24 off)
R2,R22, R51,R53	1M2 (4 off)
R3,R4, R7,R9 R21,R28, R29,R36	10k (8 off)
R5,R10, R11,R26, R58	1k (5 off)
R23,R24, R32–R35, R63	4k7 (7 off)
R27, R38–R40	47k (4 off)
R43,R56	20k (2 off)
R54	200k
R55	510k

All resistors ¼W 5%

VR1,VR2	100k mono rotary (2 off)
VR3	10k log mono rotary
VR6	1M mono rotary
VR7	100k skeleton

CAPACITORS

C1,C2, C4,C6, C13,C15, C29,C30, C33	1µ 63V electrolytic (9 off)
C3,C7, C9,C10, C17,C37	100n polyester (6 off)
C5,C16	15n polyester (2 off)
C8	470p polystyrene
C18	15p polystyrene
C19,C31, C32,C35	4µ7 63V electrolytic (4 off)
C20,C21	1n polystyrene (2 off)
C22, C24–C27, C34,C36	22µ 16V electrolytic (7 off)
C23	47µ 25V electrolytic

SEMICONDUCTORS

D1–D5	1N4148 (5 off)
TR1	BC549
TR2	BC213
IC1	324
IC2	LM13600
IC3	TL082
IC4	4046
IC5	TDA1022

SWITCHES

S1,S2	push make (2 off)
S3,S4	min s.p.d.t. (2 off)

MISCELLANEOUS

Battery clip; p.c.b. clips (4 off); knobs (4 off); 8-pin i.c. socket; 14-pin i.c. socket; 16-pin i.c. socket (3 off); mono jack socket (2 off); p.c.b. available from Becker Phonosonics.

WIND AND RAIN
RESISTORS

R1,R8, R12–R16, R20,R25, R30,R31, R37, R41–R46, R48	100k (19 off)
R2,R17, R18,R22	1M2 (4 off)
R3,R7, R9,R21, R28,R29, R36	10k (7 off)
R4,R5, R10,R11, R26	1k (5 off)
R23,R24, R32–R35	4k7 (6 off)
R27,R38, R39	47k (3 off)
R40	200k
R47	300k
R49	2M2

All resistors ¼W 5%

VR1, VR2, VR5	100k mono rotary (3 off)
VR3	10k log mono rotary
VR4	1M mono rotary

CAPACITORS

C1,C15	1µ 63V electrolytic (2 off)
C2,C3, C9,C13, C37	100n polyester (5 off)
C5,C8, C18	150p polystyrene (3 off)
C6,C17, C20,C21	1n polystyrene (4 off)
C7,C11	15n polyester (2 off)
C12	470p polystyrene
C14	330p polystyrene
C19	4µ7 63V electrolytic
C22, C24–C28	22µ 16V electrolytic (6 off)
C23	47µ 25V electrolytic

SEMICONDUCTORS

TR1	BC549
IC1	324
IC2	LM13600
IC3	TL082
IC4	4046
IC5	TDA1022

SWITCHES

S3–S5	min. s.p.d.t. (3 off)

MISCELLANEOUS

Battery clip; p.c.b. clips (4 off); knobs (5 off); 8-pin i.c. socket; 14-pin i.c. socket; 16-pin i.c. socket (3 off); mono jack socket; p.c.b. available from Becker Phonosonics.
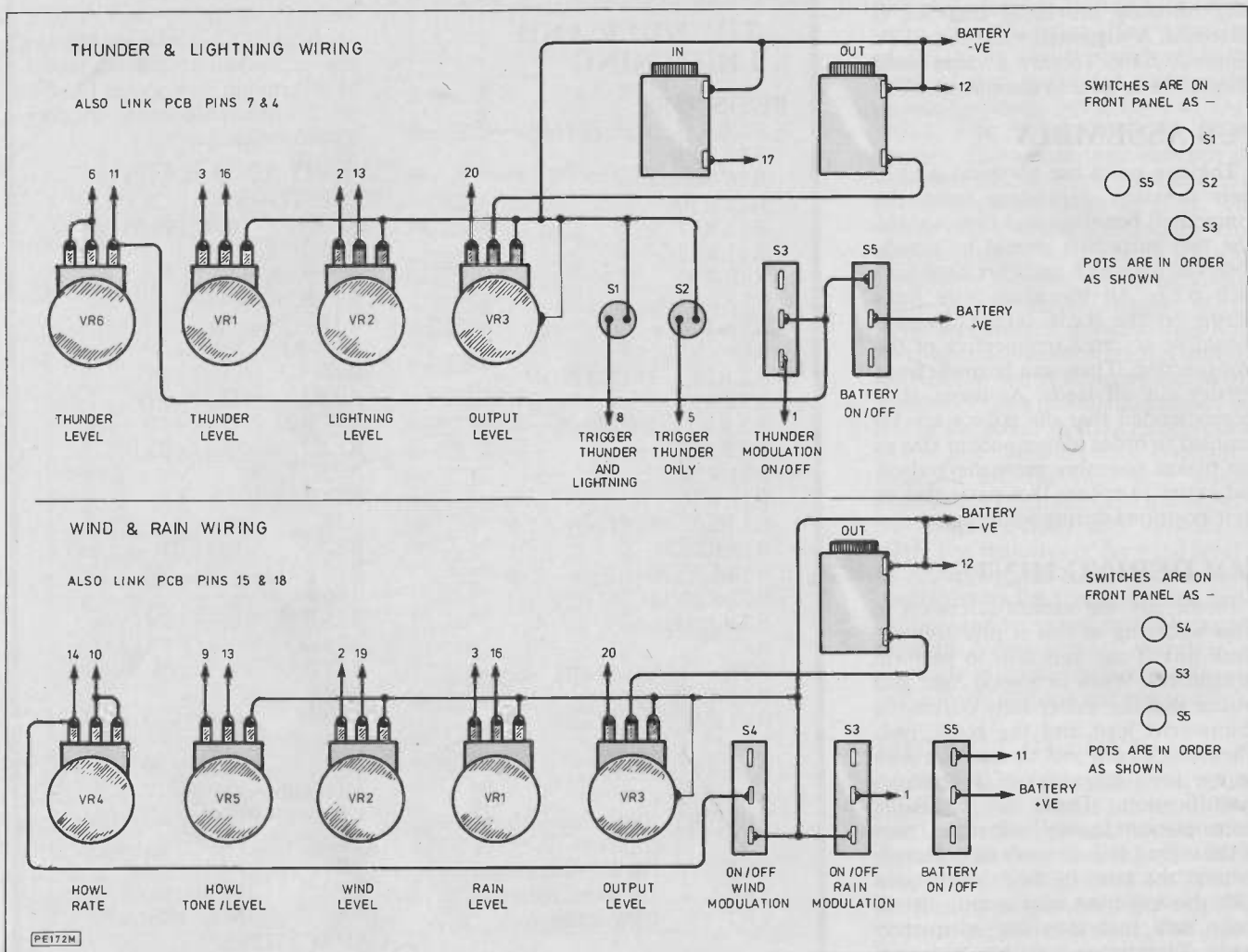
Fig. 5. *Wiring details of the complete unit*

to have been haphazardly routed by a drunken sparrow.

SETTING UP

The only alignment needed is the setting of VR7. This is not critical and is entirely done while listening to the unit. Start off with it at full clockwise rotation, with the thunder level and master output controls fully up and modulation on. With S1 and S2 unpressed reduce VR7 until no thunder is heard.

The setting of the panel controls are a matter of personal preference related to the sound effect required. What ever settings are chosen, aspiring film and stage producers can now stop blowing across microphones or bottle tops, and cease shaking wobbleboards whilst soaking under hand held showers. Electronics has come to the rescue yet again!

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Linkafex Fuzz	SET 209L	£17.54	£23.24
Linkafex Modulo	SET 211	£19.71	£25.41
Linkafex Overdrive	SET 215	£19.43	£25.13
Linkafex Phaser	SET 205	£28.68	£34.38
Linkafex Sustain	SET 223	£20.77	£26.47

PCB SERVICE

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Echo-Reverb (Sep 84)	PCBS 218A-B	(SET)	£8.14
Mini Sampler (Jan 85)	PCBS 234A-B	(SET)	£11.00
Mixer (Jan 86)	PCB 229A	(EACH)	£3.10
Noise Gate (May 85)	PCB 227A		£4.35
Phaser (Oct 84)	PCBS 226A-B	(SET)	£7.44
Ring Mod (Dec 84)	PCB 231A		£5.27
Scope Simul (Dec 85)	PCB 247A		£3.33
Signal Gen (Feb 85)	PCB 233A		£4.53
Storm Effects (Jun 86)	PCB 250A	(EACH)	£6.07

* = Kit as Published

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1000	51.22	4.02
2000	95.01	6.36
3000	133.23	O/A
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8	P	4	10.37	2.10
10	S	5	11.34	2.20
12		6	12.57	2.25
16		8	14.98	2.60
20		10	20.15	3.04
30		15	25.06	3.10
60		30	51.35	4.90
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4010	21p	4049	18p	4516	36p
4011	13p	4050	18p	4517	32p
4012	13p	4051	38p	4518	38p
4013	18p	4052	37p	4519	30p
4014	35p	4053	40p	4520	38p
4015	34p	4060	40p	4521	90p
4016	18p	4063	52p	4522	52p
4017	31p	4066	22p	4526	36p
4018	33p	4067	130p	4527	44p
4019	28p	4068	13p	4528	40p
4020	35p	4069	13p	4529	75p
4021	35p	4070	13p	4532	52p
4022	35p	4071	13p	4553	150p
4023	13p	4072	13p	4555	30p
4024	28p	4073	13p	4556	38p
4025	13p	4075	13p	4583	60p
4026	60p	4076	45p	4584	30p
4027	18p	4077	13p	4585	42p
4028	29p	4081	13p		
4029	35p	4082	13p		
4030	17p	4085	40p		
4031	90p	4086	32p		
4032	54p	4089	80p		
4033	80p	4093	18p		
4034	180p	4094	48p		
4035	45p	4098	50p		
4036	180p	4501	30p		
4037	75p	4502	38p		
4038	45p	4503	32p		
4039	190p	4505	55p		
4041	36p	4506	38p		
		4507	33p		

74LS SERIES

74LS00	15p	74LS78	28p	74LS192	50p
74LS01	15p	74LS83	43p	74LS193	50p
74LS02	15p	74LS85	43p	74LS195	52p
74LS03	15p	74LS86	22p	74LS196	52p
74LS04	15p	74LS90	38p	74LS197	52p
74LS05	15p	74LS91	75p	74LS221	52p
74LS08	15p	74LS92	38p	74LS240	55p
74LS09	18p	74LS93	37p	74LS241	55p
74LS10	15p	74LS95	55p	74LS242	52p
74LS11	18p	74LS96	60p	74LS243	52p
74LS12	18p	74LS107	32p	74LS244	55p
74LS13	37p	74LS109	36p	74LS245	90p
74LS14	53p	74LS112	32p	74LS247	65p
74LS15	30p	74LS113	32p	74LS251	52p
74LS20	15p	74LS114	32p	74LS253	56p
74LS21	18p	74LS122	46p	74LS256	60p
74LS22	18p	74LS123	38p	74LS257	42p
74LS24	37p	74LS125	30p	74LS258	42p
74LS27	18p	74LS126	36p	74LS259	58p
74LS28	20p	74LS132	36p	74LS260	38p
74LS30	15p	74LS136	35p	74LS266	28p
74LS32	17p	74LS138	35p	74LS273	52p
74LS33	25p	74LS139	35p	74LS279	40p
74LS37	30p	74LS145	90p	74LS280	140p
74LS38	20p	74LS147	120p	74LS290	30p
74LS40	16p	74LS148	90p	74LS293	30p
74LS42	45p	74LS151	32p	74LS365	37p
74LS47	56p	74LS153	38p	74LS366	37p
74LS48	56p	74LS155	45p	74LS367	35p
74LS51	16p	74LS156	47p	74LS368	35p
74LS54	16p	74LS157	33p	74LS373	55p
74LS55	17p	74LS158	33p	74LS374	55p
74LS73	22p	74LS160	55p	74LS375	58p
74LS74	22p	74LS161	40p	74LS378	58p
74LS75	28p	74LS162	48p	74LS399	72p
74LS76	28p	74LS163	36p	74LS670	72p
		74LS164	45p		
		74LS165	65p		
		74LS166	74p		
		74LS169	65p		
		74LS170	80p		
		74LS173	45p		
		74LS174	45p		
		74LS175	45p		
		74LS190	55p		
		74LS191	55p		

74 SERIES

7400	16p	7450	30p	74150	90p
7401	16p	7454	30p	74151	70p
7402	22p	7470	30p	74153	70p
7403	16p	7472	30p	74154	90p
7404	20p	7473	30p	74157	45p
7405	30p	7474	30p	74160	70p
7406	18p	7475	30p	74163	70p
7407	30p	7481	90p	74164	80p
7408	25p	7483	45p	74166	100p
7409	29p	7485	50p	74167	180p
7413	35p	7486	30p	74174	80p
7417	32p	7489	180p	74180	50p
7420	25p	7490	30p	74192	40p
7421	22p	7492	30p	74193	45p
7430	22p	7493	45p	74393	70p
7437	32p	7496	48p		
7442	45p	74107	30p		
7447	45p	74111	52p		
		74118	62p		
		74119	85p		
		74121	30p		
		74141	55p		
		74145	70p		

COMPUTER IC'S

2114	85p	Z80BCTC	600p
2532	330p	Z80AS10	660p
27256	400p	Z80AS10/1	700p
2716	200p	Z80AS10/2	700p
2732	280p	Z80ADART	680p
2764	250p	Z80ACPU	180p
27128	250p	Z80BCPU	600p
4116	75p	Z80AP10	250p
4164	110p	Z80BP10	600p
6116	180p	Z80CTC	250p
6264	250p	Z80ACTC	250p
6502	300p		
6802	220p		
6809	340p		
6821	180p		
6840	300p		
6850	110p		
8080A	300p		
8085A	320p		
8155	360p		
8156	360p		
8212	270p		
8226	270p		
8243	250p		
8250	340p		
8251	300p		
8255	340p		
8256A	370p		
8257A	370p		
8259	300p		
8271	4400p		
8272	1300p		
8279	300p		
8283	400p		
8284	500p		
8288	1000p		
8748	750p		

LINEAR IC'S

AN-214P	200p	CA3046	45p	LA-4030	140p
AN-240P	150p	CA3048	190p	LA-4031	140p
AN-360	120p	CA3080	70p	LA-4050	130p
AN-7110	140p	CA3080E	70p	LA-4100	130p
AN-7114	160p	CA3086	55p	LA-4101	52p
AN-7115	160p	CA3089E	55p	LA-4102SK	100p
AN-7120	140p	CA3090AQ	300p	LA-4112	85p
AY3-1270	680p	CA3130E	38p	LA-4125	210p
AY3-1350	360p	CA3130S	100p	LA-4140	180p
AY3-8910	400p	CA3140E	38p	LA-4220	120p
AY3-8912	400p	CA3189E	250p	LA-4400	190p
AY5-3600	570p	CA3240E	90p	LA-4422	55p
HA-1156W	150p	HA-1388	140p	LA-4460	170p
HA-1197	160p	HA-1392	230p	LA-4461	170p
HA-1306W	150p	HA-1397	240p	LA-5112	120p
HA-1319	250p	HA-1398	240p		
HA-1342	22p	LA-1201	85p		
HA-1366WR	180p	LA-1365	120p		
HA-1366W	180p	LA-3301	115p		
HA-1377	220p	LA-3350	120p		
		LA-3361	115p		

LM301	26p	LM709 DIL	30p
LM311	35p	LM723	40p
LM324	36p	LM741 DIL	18p
LM325	45p	LM741 MET	45p
LM339	45p	LM747	58p
LM348	60p	LM748	35p
LM380	100p	LM1458	33p
LM381	160p	LM3900	30p
LM382	130p	M-51513L	180p
LM387	100p	M-51515BL	280p
		M-51516	280p
		M-51517L	280p
		MB3712	150p
		MB3730	200p
		MB3756	260p
		MC1327	70p
		NE555	20p
		NE556	40p
		NE565	110p
		SAS560	110p
		SAS570	140p
		SN76003N	140p
		SN76110N	70p
		SN76115	70p
		T2000	52p
		TA-7120	58p
		TA-7137P	83p
		TA-7193P	400p
		TA-7200	200p
		TA-7201	200p
		TA-7204	110p
		TA-7205	80p
		TA-7222AP	120p
		TBA120	100p
		TBA120S	45p
		TBA395	60p
		TBA520	60p
		TBA540	100p
		TBA560	100p
		TBA750	90p
		TBA800	90p
		TBA810S	75p
		TBA820	75p
		TBA890	150p
		TBA950	90p
		TCA270	90p
		TCA800	70p
		TCA940	100p
		TDA1170	200p

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CONSTRUCTIONAL PROJECT

GUITAR TRACKER

BY R. A. PENFOLD

Turns an ordinary electric guitar into a versatile synthesiser

MOST guitar effects units process the output of the guitar in a fairly straightforward manner, usually just using filtering or distortion generation of some description. Accordingly, the sound is significantly modified, but still retains many characteristics of the original, and still sounds essentially like a guitar. There is an alternative and somewhat more complex approach to things, which enables sounds totally unlike a guitar to be produced, and considerably enhances

VCO, and a simple attack/decay envelope generator. A low frequency oscillator (LFO) to frequency modulate the VCO is also included. Triangular and squarewave output waveforms are available. This set-up enables sounds totally unlike those of a guitar to be produced. For example, the normal envelope shape of a guitar with its fast attack and slow decay can be replaced with an envelope having a slow decay and fast attack with (perhaps) the LFO used to give a fairly high frequency

tor monophonic synthesiser. Of course, the unit is only monophonic, and is completely unusable with more than one note at a time.

SYSTEM OPERATION

While this unit is not amongst the most simple of effects units, as can be seen from the block diagram shown in Fig. 1, the number of stages has been kept well within the bounds of reason.

The input signal is fed to a buffer stage which provides a suitably high
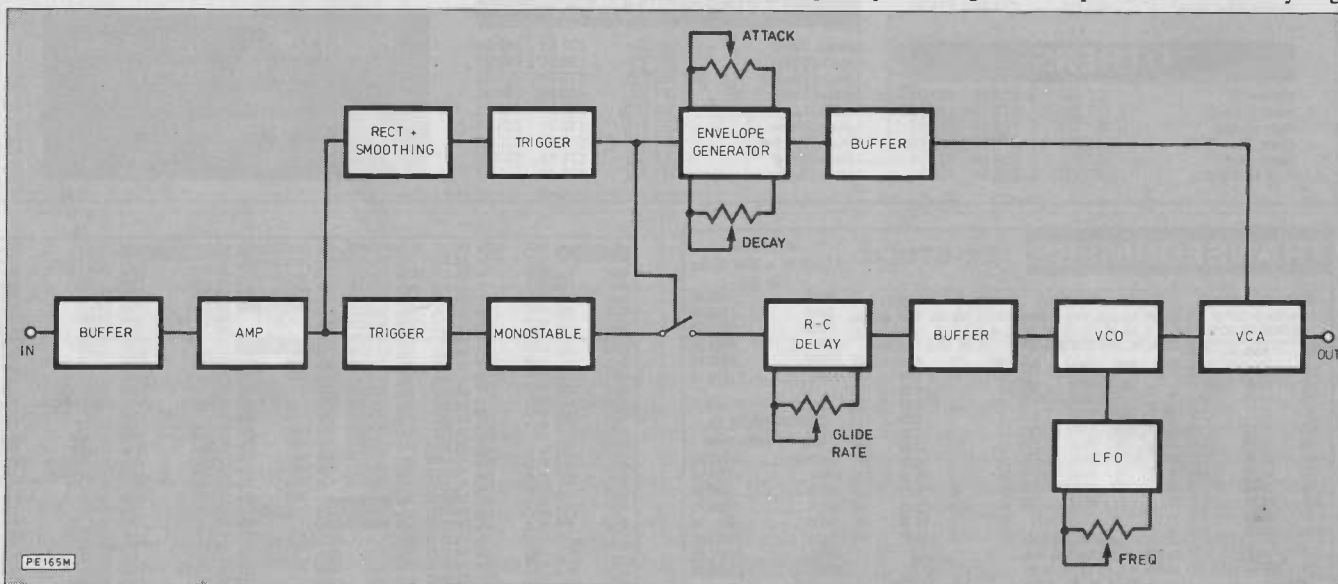
Fig. 1. *Block diagram of the Guitar Tracker*

the guitarist's pallet of sounds. This is to convert the output of the guitar to a d.c. voltage using a frequency-to-voltage converter, and to then use this voltage to control a voltage controlled oscillator (VCO). While at first sight this may seem a rather pointless and over-complex way of doing things, it gives immense versatility. With suitable circuitry to process the control voltage and the output of the oscillator it enables the guitarist to obtain any sound that can be produced using an ordinary synthesiser.

A full guitar synthesiser is extremely complex, being comparable to a normal keyboard synthesiser in this respect. However, very good results can be obtained using a relatively simple design. This unit consists of a basic frequency-to-voltage converter plus

vibrato. With either type of waveform this gives a sound which is far removed from that usually associated with a guitar. Using fairly fast attack and decay times an organ type sound can be obtained, and with a long time constant in the frequncy-to-voltage converter a true glide (portamento) effect can be produced. The output signal can be processed using guitar effects units such as phasers and flangers to further increase the range of available sounds, and most effects units work very well with the unit (particularly when using the squarewave output). Although primarily intended for use with a guitar, this device does in fact have potential for use with any electric or electronic instrument, and in particular it could use to good effect with a single oscilla-

input impedance, and the signal is then amplified. The amplified signal is then fed into two sets of processing stages; one to generate the control voltage and output signal, and the other to generate a gate signal for the envelope shaper. Taking the control voltage generator, etc. first, a Schmitt trigger circuit is used to generate a squarewave signal from the amplified guitar signal. The output waveform from a guitar is one that can easily generate spurious output pulses from a squaring circuit, which in this case would be reflected in an excessive output voltage from the control voltage generator, and the wrong pitch from the VCO. In order to avoid this the trigger circuit has been given a large amount of hysteresis.

The next stage is a monostable multivibrator, which is the main element in

the frequency-to-voltage converter circuit. A simple pulse shaper circuit is used to produce very brief negative pulses which are used to trigger the monostable. The output pulses from the monostable have their duration set by a C-R timing network, and for practical purposes the pulse length is independent of the input frequency. The average output voltage of the monostable is therefore proportional to the input frequency. If (say) a 500Hz signal gave an output signal with a one to one mark-space ratio, the average output voltage would be half the peak potential of the output pulses. Reducing the input frequency to 250Hz would halve the number of output pulses in a given period of time, and would give a mark-space ratio of 1:3. The average output voltage would then be one quarter of the peak value. Obviously the required linear relationship between input frequency and average output voltage is obtained, but only provided the input frequency is kept below a certain critical figure. In our example this figure is 1kHz, as above this frequency one input pulse will trigger the monostable, and the next trigger pulse will occur before this first output pulse has ended. This results in some trigger pulses having no effect on the unit, and the average output voltage failing to reach the correct value. Fig. 2 helps to explain the function of the monostable.

Provided the input frequency is kept below the critical figure a monostable multivibrator, despite being an extremely simple type of frequency to voltage converter, provides extremely good linearity over the audio frequency range where the rise and fall times of the output signal are negligible. Of course, the output signal must be smoothed to give a reasonably ripple free d.c. voltage, and this is achieved using a simple R-C smoothing circuit. An electronic switch is included in series with the output of the monostable, and this is controlled by the gate pulse from the envelope generator.
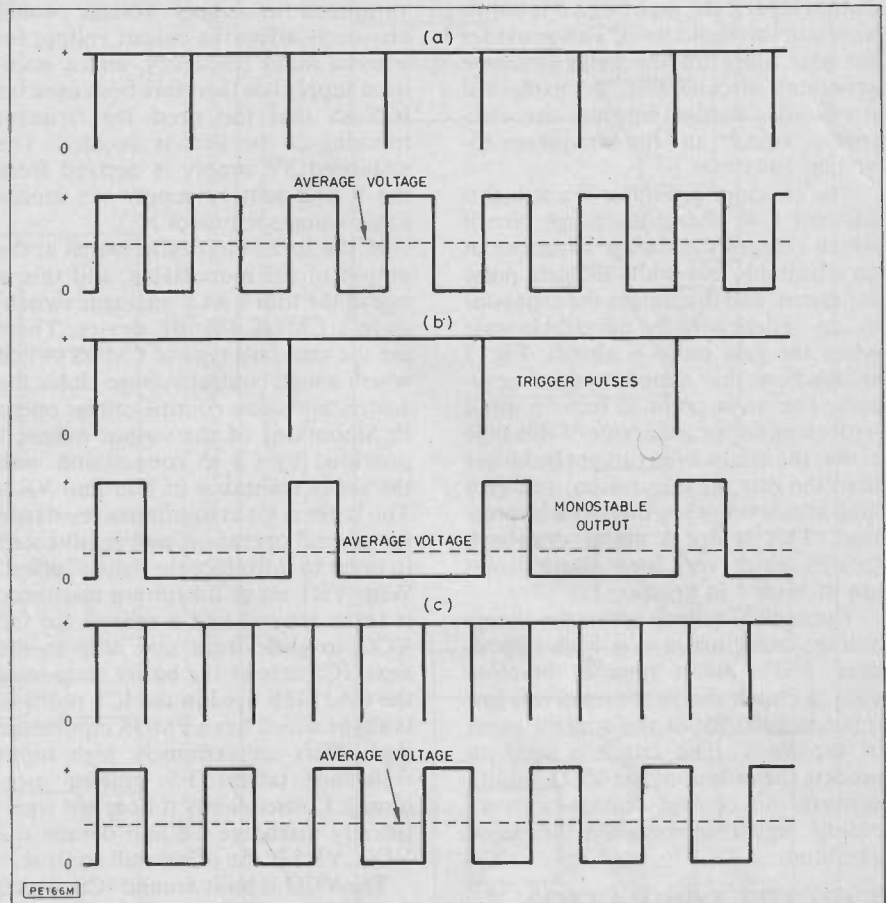
Fig. 2. *Av. o/p voltage proportional to i/p frequency*

This switch only connects the output of the monostable through to the smoothing circuit when the gate pulse is present.

The practical result of this is that with no input signal, or only a low input level, the smoothing circuit is cut off from the output of the monostable. The smoothing circuit feeds into a buffer amplifier which has an extremely high input resistance, and the control voltage is consequently maintained indefinitely. This enables the unit to produce a valid output frequency even after the output from the guitar has ceased.

A variable resistance is utilised in the R-C smoothing circuit, and normally this is set at a low value so that the converter responds almost instantly to changes in the input frequency. By using a high value the time constant of the smoothing network is made quite long (a few hundred milliseconds), and the output glides from one note to another at the required rate, just like the glide facility of a conventional synthesiser. This is something that can not normally be achieved using a guitar as the frets of the fingerboard only permit semitone jumps in pitch.

The next stage is the VCO, and it is essential that this is a type which has excellent control voltage to output frequency linearity. To an extent the offset null control in the preceding buffer stage can trim out any misstracking, but only to limited extent. The VCO used in this design is a simple and inexpensive type, but it nevertheless provides excellent linearity right down to zero volts, and it provides accurate tracking over a range of about four octaves or so. An LFO can be used to provide vibrato, and the modulation frequency is adjustable from around 0·5Hz to 10Hz.

The first stage in the envelope shaper is a rectifier and smoothing circuit. The resultant d.c. signal is fed to a trigger circuit, and this produces a high
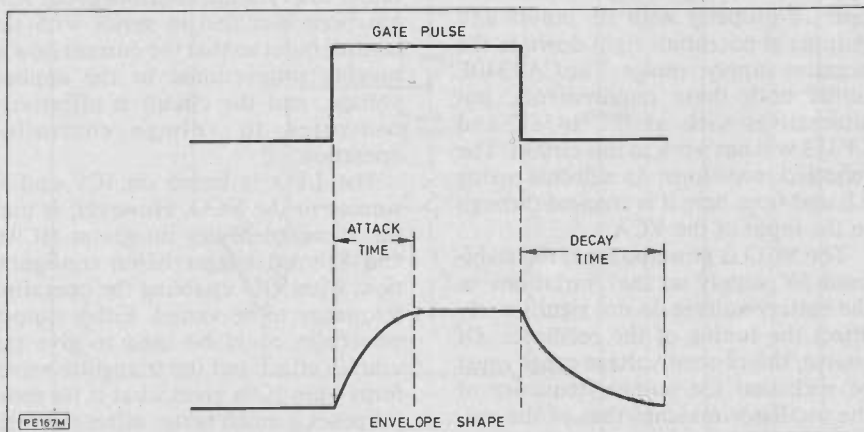
Fig. 3. *Envelope shape derived from gate pulse*

output level if the input signal is above a certain threshold level. This provides the gate pulse for the main envelope generator circuit, and, as explained previously, it also controls the electronic switch in the frequency-to-voltage converter.

The envelope generator is a straightforward C-R charge/discharge circuit which charges the storage capacitor at an adjustable rate while the gate pulse is present, and discharges the capacitor at an independently adjustable rate when the gate pulse is absent. Fig. 3 shows how this simple system operates. The main point to bear in mind with an envelope generator of this type is that the attack time can not be longer than the gate pulse duration, and very long attack times are therefore impractical. This is not a major drawback though, since very long attack times are little used in practice.

The control voltage across the charge storage capacitor is at a high impedance, and a buffer stage is therefore used to match this to the relatively low input impedance at the control input of the VCA. The latter is used to process the output of the VCO, and to convert the control voltage into an output signal of roughly the same amplitude.

CIRCUIT OPERATION

Fig. 4 shows the circuit diagram for the frequency-to-voltage and VCO stages, while Fig. 5 shows the circuit diagram for the envelope shaper and LFO stages.

Starting with the frequency-to-voltage converter, IC1a is a non-inverting buffer stage which provides an input impedance of 47k. This is followed by IC1b which is an inverting amplifier which has a preset gain of between zero and one hundred times. This enables the unit to operate with a wide range of guitar pick-ups. The output of IC1b is direct coupled to the input of the next stage, which is a conventional operational amplifier Schmitt trigger circuit based on IC2. R7 introduces the hysteresis and it has been given a fairly low value so that a suitably high degree of hysteresis is applied to the circuit.

The monostable is a 555 (IC4) connected in the appropriate fashion. In fact a low power (L555CP or ICM 7555) version of the 555 has been specified for IC5, partly in order to keep the current consumption of the unit down to a reasonable level, but also to avoid problems with noise spikes being modulated onto the supply lines and breaking through to the output. R8 and C7 produce an output pulse duration of just over 1 millisecond, which enables the frequency-to-voltage converter to operate at frequencies of up to almost 1kHz. Any

variations in supply voltage would obviously affect the output voltage for a given input frequency, and a stabilised supply has therefore been used for IC5 so that the need for frequent retuning of the unit is avoided. The stabilised 5V supply is derived from the 9 volt battery supply via monolithic voltage regulator IC3.

IC10a is the electronic switch at the output of the monostable, and this is one of the four s.p.s.t. analogue switches in a CMOS 4016BE device. These are the standard type of CMOS switch where a high control voltage closes the switch, and a low control voltage opens it. Smoothing of the output pulses is provided by C8 in conjunction with the series resistance of R11 and VR2. The latter is set at minimum resistance for normal operation, and is advanced in order to introduce the "glide" effect. With VR1 set at maximum resistance it takes around half a second for the VCO to glide from one note to the next. IC5 acts as the buffer stage, and the CA3140E used in the IC5 position is a type which has a PMOS input stage that offers an extremely high input resistance (about 1·5 million megohms). Consequently it does not significantly discharge C8 and detune the VCO. VR3 is the offset null control.

The VCO is built around IC6, which operates as what is close to being a conventional Miller integrator/Schmitt trigger oscillator. IC6a functions as the Miller integrator and provides a triangular output waveform, while IC6b operates as the Schmitt trigger and produces a squarewave output signal. The circuit differs from the conventional configuration in that feedback from the trigger to the intergrator is via TR1 and R14 rather than just by way of a timing resistor, and a variable bias is fed to the inputs of IC6a by way of R12 and R13. This bias is the control voltage, and although the circuit may appear to be rather crude, it gives excellent linearity with no offset voltage needed before oscillation commences. The latter is dependent upon IC6 being a type which can operate properly with its inputs and outputs at potentials right down to the negative supply voltage. The CA2340E fulfils both these requirements, but alternatives such as the 1458C and LF353 will not work in this circuit. The required waveform is selected using S2, and from here it is coupled through to the input of the VCA.

The VCO is powered from the stabilised 5V supply so that variations in the battery voltage do not significantly affect the tuning of the oscillator. Of course, the control voltage range must be such that the output frequency of the oscillator matches that of the guitar, and VR4 is adjusted to give accurate tracking. VR4 has been made a

front panel control so that the tuning can be readily retrimmed whenever necessary, but the circuit is sufficiently stable to make frequent readjustment unnecessary.

ENVELOPE SHAPER

Turning now to Fig. 5, the output signal from the amplifier stage is rectified and smoothed by D1, D2, C11 and R21. IC7 operates as the Schmitt trigger and it has a moderate amount of hysteresis provided by R23. The smoothing circuit necessarily has quite fast attack and decay times, and the hysteresis prevents the ripple on the smoothed signal from causing spurious operations of the trigger circuit.

IC7's output is used to directly drive the control input of IC10a at the output of the monostable circuit (Fig. 4). It is also used to directly control IC10b, which is used in the charge circuit of the envelope generator's storage capacitor C12. IC10b is therefore switched on whenever the gate pulse is present, and it causes C12 to be charged via VR6 and R26. VR6 enables the attack time to be varied from a minimum of only about 40ms to a maximum of about one second. TR2 acts as an inverter, and its output signal drives the control input of IC10c. This switch is turned on when the gate pulse is absent, and at the end of the gate pulse it therefore discharges C12 via R27 and VR7. The latter gives an adjustable decay time with a range of approximately 40ms to 4 seconds. Note that one switch in IC10 is not required in this circuit, and it is simply ignored.

The VCA is a conventional type built around one of the operational transconductance amplifiers and buffer stages in IC8. The other amplifier and buffer stage of IC8 are not required, and no connections are made to either of these. TR3 is an emitter follower which provides the buffering between the output of the envelope generator and the control input of the VCA. The VCA is actually current rather than voltage controlled, but R30 has been included in series with the control input so that the current flow is roughly proportional to the applied voltage, and the circuit is effectively converted to voltage controlled operation.

The LFO is based on IC9 and is similar to the VCO. However, it uses the standard Miller integrator (IC9a) and Schmitt trigger (IC9b) configuration, with VR8 enabling the operating frequency to be varied. Either output waveform could be used to give the vibrato effect, but the triangular waveform from IC9a gives what is for most purposes a much better effect than the squarewave output from IC9b would produce. S3 enables the effect to be
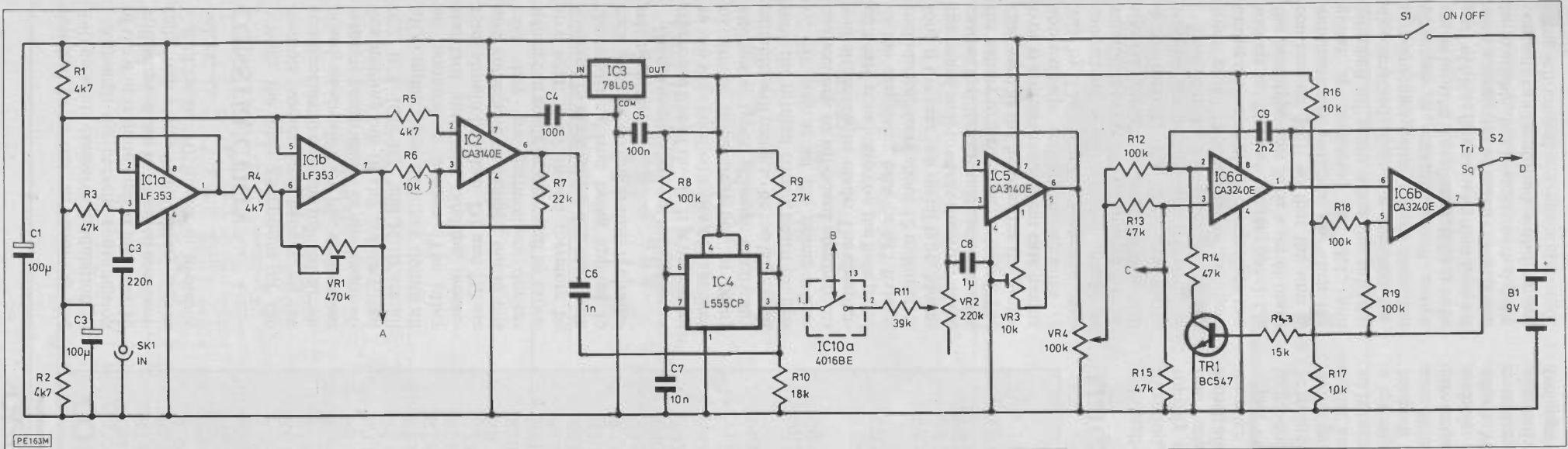
Fig. 4. *(Above) Circuit diagram of the F to V and VCO stages*

Fig. 5. *(Below) Circuit diagram of the envelope shaper and LFO stages*
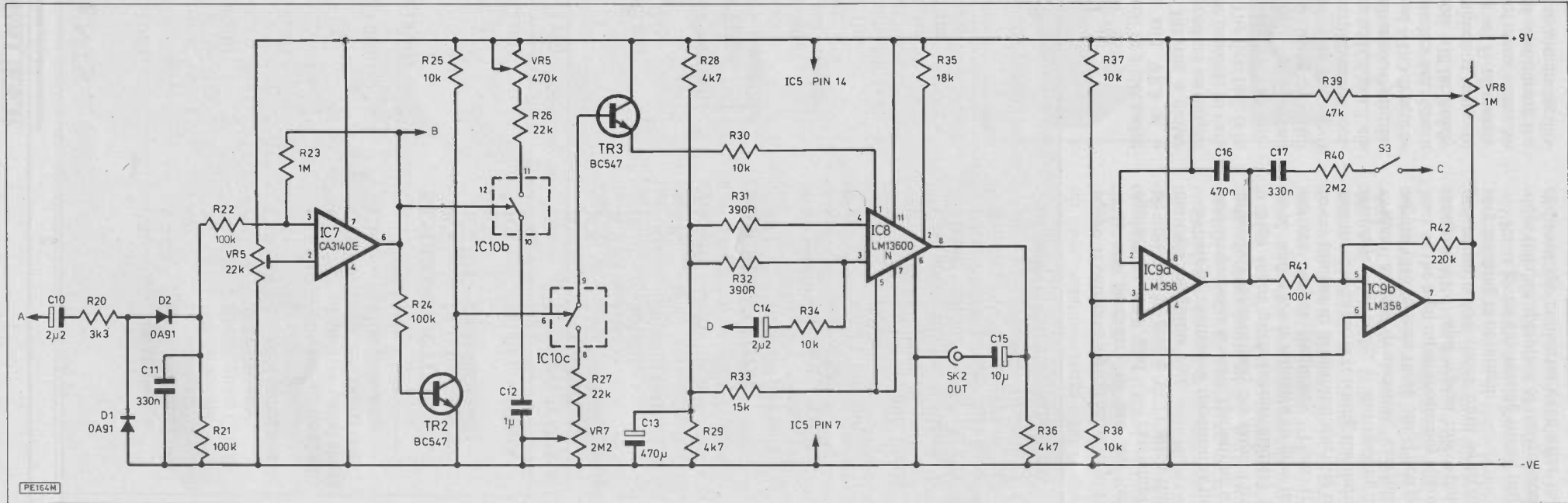
switched in or out, as required, and R40 prevents excessive modulation.

Although the current consumption of the unit is quite high at just over 20 milliamps, it can be powered economically from a large 9 volt battery such as a PP9 or six HP7 cells in a plastic holder.

CONSTRUCTION

With the only exceptions of the controls, sockets and battery, all the components fit onto the printed circuit board, as detailed in Fig. 6. In most respects construction of the board offers nothing out of the ordinary, but IC2, IC5, IC6, IC7 and IC10 are all MOS input types, and they should all be mounted in holders. The other standard antistatic handling precautions should be taken. D1 and D2 are also vulnerable to damage, but in this case they are germanium devices which can easily be damaged by excessive heat. They should therefore be soldered in place taking due care, with the soldering iron being applied to each joint for no longer than is absolutely necessary.

Do not overlook any of the link wires (there are five of them). It is important to use the specified types of capacitor or similar minature types, as many alternative types, although electrically suitable, will prove to be too large to fit onto the printed circuit board properly. Fit pins at all the points where connections to off-board components will ultimately be made. The completed board is mounted on the base panel of the case using 6BA or M3 fixings, including spacers about 12 millimetres long if the case is a metal type. Mount the board well towards the front of the case so that there is sufficient space for the battery to the rear of the board. The case used as the housing for the prototype is a metal instrument case having approximate outside dimensions of 205 by 134 by 50 millimetres. Any cabinet of a similar size should be suitable, but the 205 millimetre dimension is about the smallest that will accommodate the 200 millimetre width of the printed circuit board.

The controls are mounted on the front panel, but in order to avoid undue crowding of the controls the two sockets are fitted on the rear panel. On the prototype unit S1 is a set of make contacts on SK1, so that the unit is automatically switched on when the guitar is connected to SK1, and switched off again when the guitar is disconnected. This is a common feature amongst guitar effects units, but obviously a separate on/off switch could be used if preferred. If S1 is to be part of SK1, it is unlikely that a socket with a single set of make contacts will be available, but a socket with d.p.d.t. contacts can be utilised, with four tags being left unused.

COMPONENTS . . .

RESISTORS

R1,R2, R4,R5, R28,R29, R36	4k7 (7 off)
R3,R13, R14,R15, R39	47k (5 off)
R6,R16, R17,R25, R30,R34, R37,R38	10k (8 off)
R7,R26, R27	22k (3 off)
R8,R12, R18,R19, R21,R22, R24,R41	100k (8 off)
R9	27k
R10,R35	18k (2 off)
R11	39k
R15,R33, R43	15k (3 off)
R20	3k3
R23	1M
R31,R32	390 (2 off)
R40	2M2
R42	220k

All resistors ¼W 5% carbon

POTENTIOMETERS

VR1	470k sub-min. hor. preset
VR2	220k 1in.
VR3	10k sub-min. hor. preset
VR4	100k 1in.
VR5	22k sub-min. hor. preset
VR6	470k 1in.
VR7	2M2 1in.
VR8	1M 1in.

CAPACITORS

C1,C2	100µ 10V radial elect (2 off)
C3	220n carbonate
C4,C5	100n ceramic (2 off)
C6	1n carbonate
C7	10n carbonate
C8,C12	1µ carbonate (2 off)
C9	2n2 carbonate
C10,C14	2u2 63V radial elect. (2 off)
C11,C17	330n carbonate (2 off)
C13	470µ 10V radial elect.
C15	10µ 25V radial elect.
C16	470n carbonate

SEMICONDUCTORS

IC1	LF353
IC2,IC5 IC7	CA3140E (3 off)
IC3	78L05 (5V 100mA reg.)
IC4	L555CP or ICM7555
IC6	CA3240E
IC8	LM13600N
IC9	LM358
IC10	4016BE
TR1– TR3	BC547 (3 off)
D1,D2	OA91 (2 off)

MISCELLANEOUS

SK1	standard jack with d.p.d.t. contacts (S1)
SK2	standard jack socket
S1	part of SK1
S2	s.p.d.t. sub-min. toggle
S3	s.p.s.t. sub-min. toggle
B1	9V (PP7, etc.)

Case about 205mm × 134mm × 51mm; control knobs (5 off); P.c.b. PE111; battery connector; 8-pin d.i.l. i.c. holders (7 off); 14-pin d.i.l. i.c. holder; 16-pin d.i.l. i.c. holder; Veropins, fixings, etc.

ADJUSTMENT

Initially set VR5 well in a clockwise direction, and VR1 and VR3 at a roughly mid-setting. Playing a guitar into the unit should produce an output signal, and it should be possible to vary the pitch using VR4. The first task is to adjust VR4, and possibly VR3 as well, to produce accurate tracking. This can be most easily achieved using an audio signal generator to provide the input signal, and a crystal earphone connected between IC2 pin 6 and IC6 pin 7 via a 56k resistor to simultaneously monitor both the guitar and VCO frequencies. When the two pitches are close a low frequency beat note will be clearly audible, and this makes it easy to adjust VR4 correctly as it is merely necessary to set it for zero beat. An alternative method of monitoring the two signals would be to use an oscilloscope. If you have a good sense of pitch it is not necessary to use any test equipment at all, and VR4 can simply be adjusted to give a VCO pitch that matches the guitar note.

Whatever method of monitoring the two frequencies is used, the setting up procedure is essentially the same. First a high input pitch (about 800Hz) is used, and VR4 is adjusted to give the correct output frequency. Then try lower pitches to determine whether or not the oscillator is tracking the input frequency correctly. If mistracking is evident at low frequencies, carefully adjust VR3 to trim these out. Then go back to the high input frequency again, readjust VR4, and repeat this whole procedure a few times until satisfactory tracking is obtained.

VR1 is given any setting which provides reliable operation of the frequency-to-voltage converter even after the
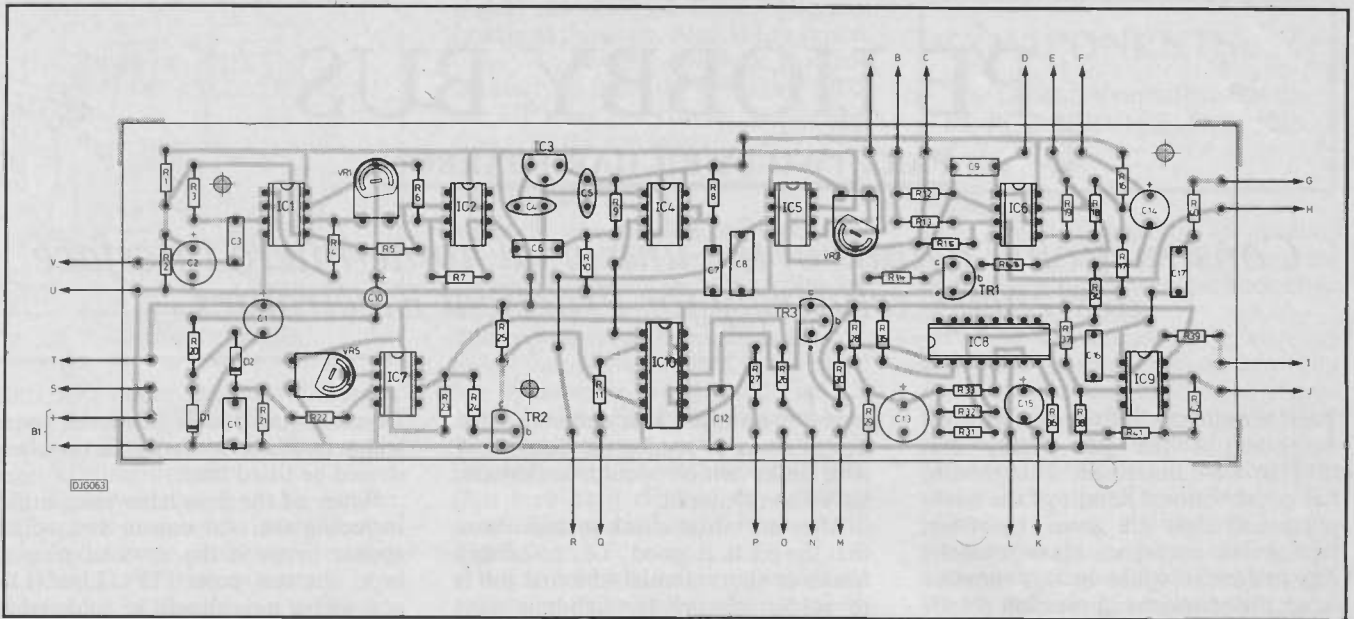
Fig. 6. *P.c.b. component layout (less than full size)*

signal from the guitar has decayed somewhat from its initial high level. On the other hand, it should not be set for such a high level of sensitivity that spurious triggering of the unit and unwanted output signals are easily produced. VR5 is adjusted to give a gate pulse of reasonable duration, but it should not be set for a level of sensitivity that is too high or the gate pulse will extend beyond the point where the input signal for the frequency-to-voltage converter falls below an adequate level, causing the VCO control voltage to subside. It is best to set VR5 as far in an anticlockwise direction as possible, commensurate with an adequate gate pulse duration. However, it is really a matter of experimenting a little with the settings of VR1 and VR5 to determine which combination works best in practice.

The unit is then ready for testing and use. A little experimentation with the controls will soon reveal the range of sounds available. As with any effects unit it needs to be used sensibly in order to obtain good results. It is no good setting a long attack time and then playing notes at machine-gun tempo, as this would result in little or no output. A long attack time demands long, sustained notes. When using a long decay time and minimum glide time it is essential to use fast and precise fingering to avoid spurious output frequencies from the guitar which will shift the VCO from the correct frequency. Increasing the glide time slightly makes fingering precision a little less critical.

Proper operation with most guitar pick-ups is possible, but with very low output types it might be necessary to use a preamplifier ahead of this unit. Tracking over virtually the full compass of the guitar should be possible,
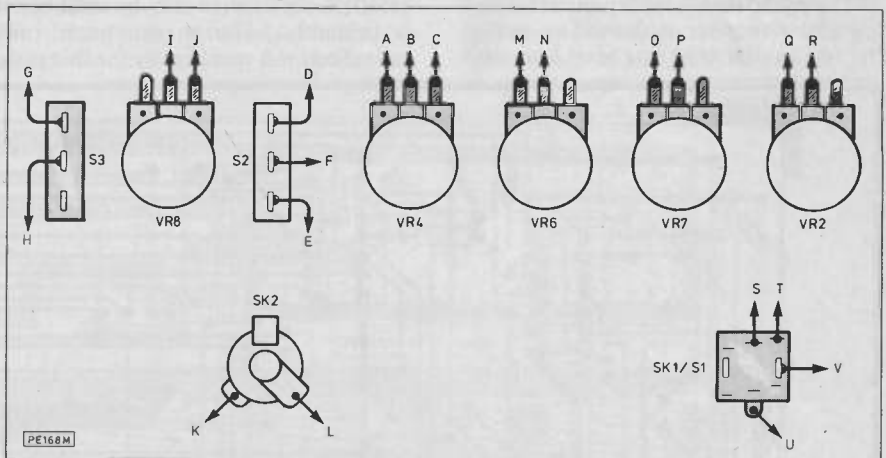
Fig. 7. *Wiring details of pots and sockets*
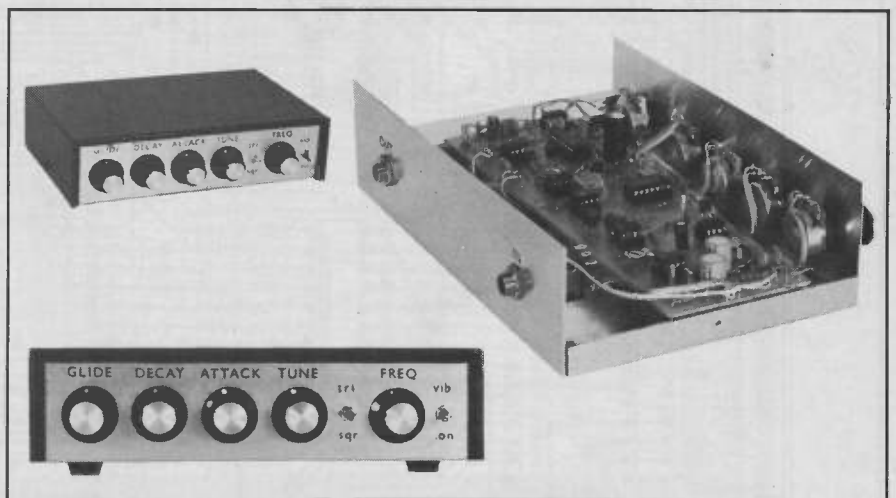
although the unit might not be able to reach the few highest notes. If operation at these notes is required reducing R8 to 68k should bring them within the range of the unit. There are numerous possibilities for the experimenter with a unit of this type, and one line of experimentation would be to interface the gate and control voltage signals to

the corresponding inputs of a synthesiser which has a linear control voltage characteristic. Note, though, that modern synthesisers have a logarithmic control voltage characteristic and could only be controlled properly via this unit with a logarithmic amplifier being used to provide the linear to logarithmic conversion. **PE**

PE HOBBY BUS

PART TWO BY RICHARD BARRON

Constructional details of the universal home-micro interface designed exclusively for Practical Electronics

LAST month, the basic operating principles of the PE Hobby Bus (PEHB) were described. This month, full constructional details of the backplane and PSU are given. However, first, let us apologise. Unfortunately, due to lack of space in this month's issue, the computer connection details and programs cannot be included. These will be given next month.

The p.c.b. design, component assembly and wiring details are shown in Fig. 2.1. As can be seen, the board is quite large yet compact. It is a double sided design so as to reduce the number of wire links which would, otherwise, have been required.

After an initial check to make sure that the p.c.b. is 'good', i.e., no broken tracks or short circuits, the first job is to solder all the through-hole pins which make the connections between the two sides of the board. For this, small pieces of wire may be used but it is probably wiser to use p.c.b. pins manufactured specifically for this task.

Despite being double sided, the board still requires a few wire links—these should be fitted later.

When all the pins have been fitted, including the odd one or two which appear between the rows of pins of i.c.s, the test point (TP), Link (LK) and wiring pins should be soldered in position. Once again it is wise to use manufactured pins, rather than odd bits of wire.

Because of the boards complexity, it should be regularly checked for dry
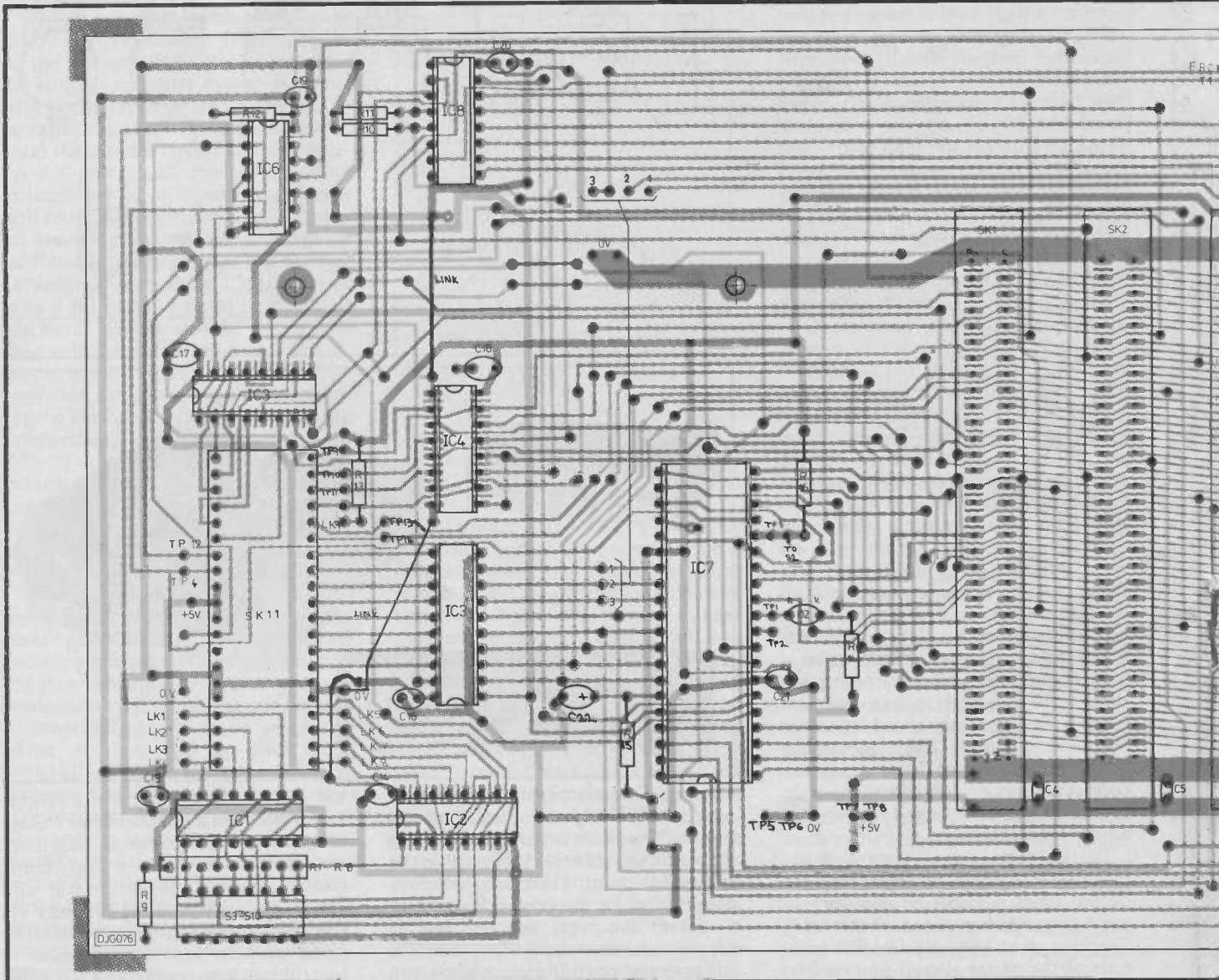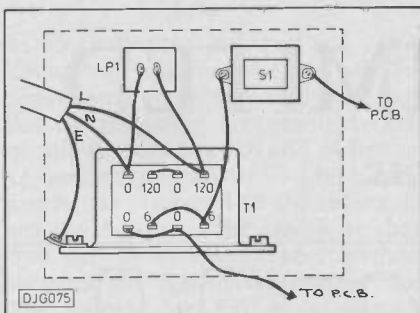
Fig. 2.2. *Power supply details*

joints and solder splashes after each stage of asembly. It is much easier to spot and rectify these faults at early stages of construction.

If all is well, so far, the smaller components such as resistors, decoupling capacitors and the rectifier should be fitted. It doesn't matter how experienced a constructor you are, double check the orientation of all polarised components as it will save at the very least, a blown fuse or two.

All of the i.c. sockets and the backplane sockets, SK1–SK10 and SK12 should now be fitted. Do not plug any i.c.s. in at this stage. Also, if you expect to be only using a few slots, it is not necessary to fit all the backplane sockets. Fit what you require as you can always fit the rest later.

POWER SUPPLY

For the sake of safety, with economy in mind, only the components which are connected directly to the mains are fitted into any form of box or housing. The transformer, mains neon and the on-off switch are all fitted into a small box as shown in Fig. 2.1 and Fig. 2.2. After the i.c.s. have been inserted into their sockets, the completed box is bolted to the p.c.b. with spacers fitted, thus keeping it clear of any obstructions. The mains wiring is shown in Fig. 2.2.

Before inserting any i.c.s. into their sockets, and obviously before connecting the power supply. The board should be thoroughly checked for good workmanship. All being well, a meter (on ohms range) should be connected across the power lines to check for short circuits. The needle (or display) will indicate that the capacitors are being charged and then fall back close to zero.

If all is well and all the wires, links and other components are correctly fitted, the i.c.s. may be inserted, checking each for correct orientation. The transformer unit should finally be mounted on the board making sure that it is clear of all components. Two holes have been allowed for on the p.c.b. for mounting purposes. It will be noticed that one of these goes through the ground line. If a metal bolt is used, it may be used as a ground connection.

Next month, final construction, the setting-up procedure, computer connections and programs in detail.
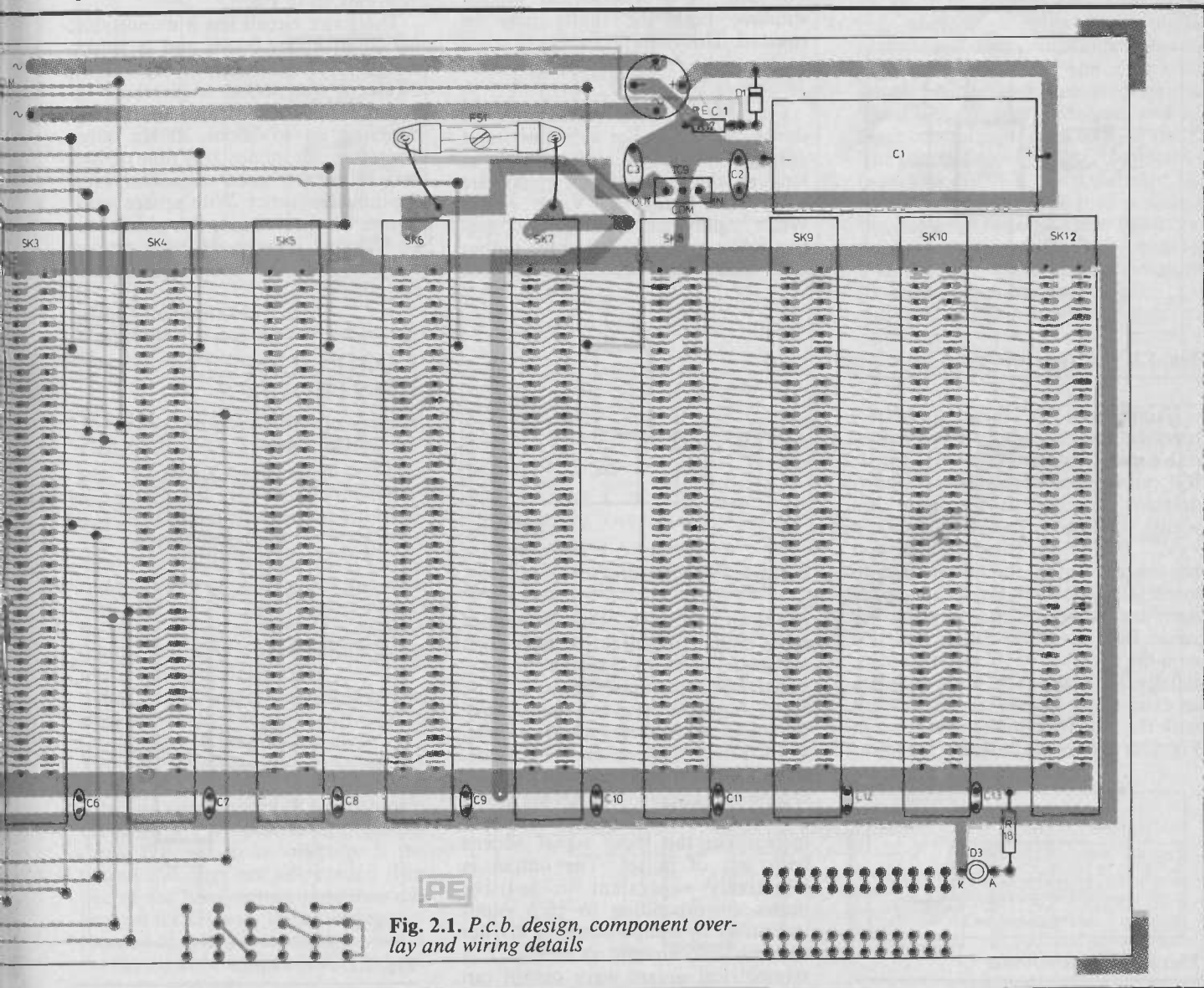
Fig. 2.1. *P.c.b. design, component overlay and wiring details*

INGENUITY UNLIMITED

A selection of readers' ideas

NOVEL 555 TIMER APPLICATIONS

Frequency doubler and symmetrical bipolar window detector

The 555 is widely used for many applications including frequency division. Here are some new applications —as a voltage window-detector and as a frequency doubler.

When the input at the trigger, pin 2, is between $\frac{1}{3}V_{cc}$ and zero volts, the output at pin 3 remains high. When the input exceeds $\frac{1}{3}V_{cc}$, the output falls low. This is a well-known property of the 555. Interestingly, it is found that even when the input voltage falls below $-0.7V$ (i.e. voltage drop of single silicon diode, V_f), the output at pin 3 falls low.
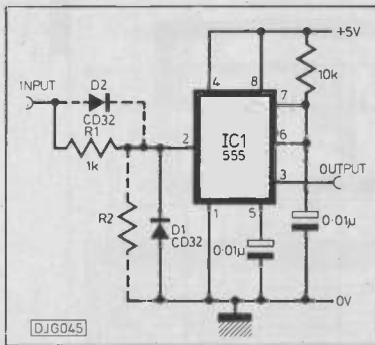
Fig. 1.1. *Window detector*

Using both of these properties together, and connecting it as a monostable multivibrator as shown in Fig. 1, IC1 can be used as a voltage-window-detector. As long as the input lies within the limits of $-V_f(\approx -0.7V)$ to $+\frac{1}{3}V_{cc}$, the output remains high and beyond the limits, the output falls to low level as shown in Fig. 2. The upper limit can be set by changing the V_{cc} value. Both the limits can be widened with the addition of R2, by the potential divider action of R1 and R2. When an extra diode is used in combination with the potential divider as shown in Fig. 2, it is possible to widen the lower
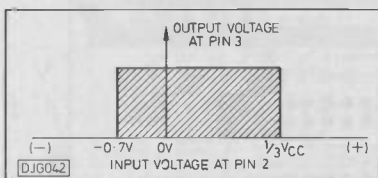
Fig. 1.2. *Window limits*
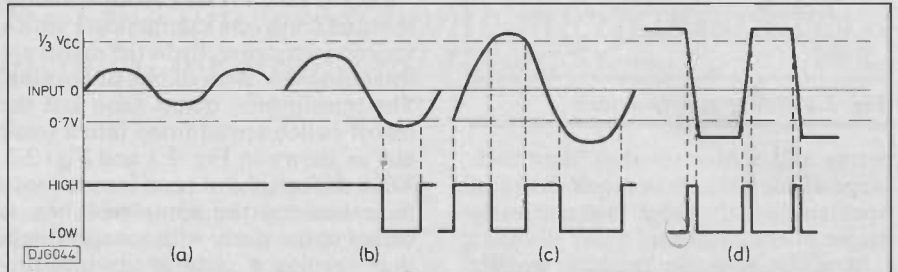
Fig. 1.3. *Frequency doubler*

limit. The upper or positive voltage limit is set by $(\frac{1}{3}V_{cc} + V_f)$. The lower or negative voltage limits is set by

$$V_f \left(\frac{R1 + R2}{R2}\right).$$

To make it a symmetrical bipolar window, both the limits may be equated. This requires to set

$$\frac{R2}{R1} = \frac{3V_f}{V_{cc}}$$

Frequency doubler connections are shown in Fig. 3. For very low input voltages, the output remains high, as long as the input signal peaks are within the limits of $-V_f$ to $+\frac{1}{3}V_{cc}$. When negative peaks exceed $-V_f$, negative pulses are generated at the output
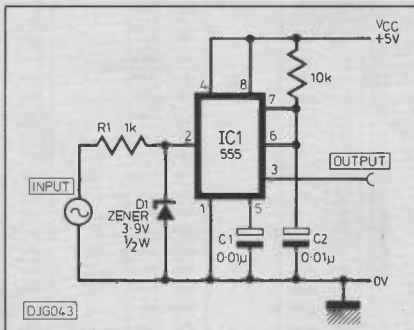
Fig. 1.4. *Doubler waveforms*

as shown in Fig. 4b. With increase of input signal, the negative pulses get widened. Thus by keeping the a.c. signal peak value V_p such that $-0.7V < V_p < \frac{1}{3}V_{cc}$, it behaves as a square wave generator, whose duty cycle is variable. With further increase of input signal, when the positive peaks exceed $\frac{1}{3}V_{cc}$, a second set of negative pulses are generated as shown in Fig. 4c. Any more increase in the input signal widens both sets of pulses. The output is effectively equivalent to positive pulses corresponding to each input transition. By using a potential divider and diode technique, as in Fig. 1, a symmetrical square wave output can

be realised. Instead of a sine wave, if a square wave input is fed in, the output consists of narrow unipolar pulses at the transitions. Obviously the output frequency is double that of the input frequency, without any need for modifications, as in Fig. 1.

The given circuit has a monostable period of about 0.1ms and it works well at low frequencies, say up to 1 or 2KHz. If the period is increased to about 1ms the circuit performs doubling up to about 200Hz only. Therefore, the monostable time period may be chosen to be consistent with the input frequency. With square wave inputs, the output, unipolar pulses can be widened if required, with proper selection of the monostable time period.

D. Venkatasubbia, India.

COMPUTER CONTROLLER

Simple circuit giving up to 15 control lines

This simple circuit allows any computer with a user port and appropriate software to switch fifteen devices, such
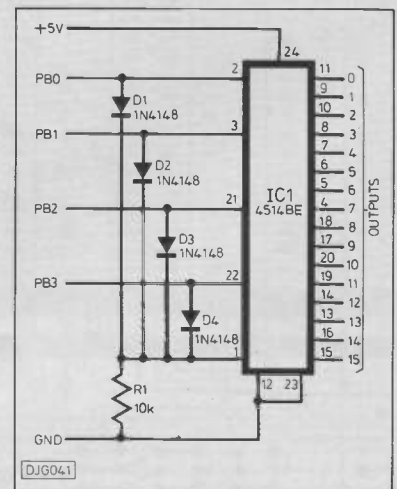
Fig. 2.1. *Port outputs*

as small motors, on and off. This circuit was built for the CBM 64. The appropriate pokes to switch each output on are easily programmed. The circuit consists of a 4514BE (4-line to 16-line converter). When a 4-bit binary number is presented to the inputs, it sets pin 1 high via the diodes, so that data may be accepted. The chip then switches the appropriate output on. The outputs are fed to a pair of Darlington chips to switch fifteen, 5V relays on. The only problem with this circuit is that only one output can be on at any time, but this can be easily overcome by connecting flip/flops to each output of IC1. The output of the flip/flops should then be connected to the Darlington driver l.c.s.

J. W. Schorah,
Yorks.

With the voltage followers reducing loading of the tuned circuit, its Q-factor can be set by an external shunt resistor.

Although 22·5MHz r.f. and video are used, the circuit will work with other signals.

A. B. Bradshaw, Beds.

DISC DRIVE INDICATOR FOR THE BBC

I am the owner of a BBC Model B micro, with disc interface. My disc-drive is 40 track, double sided, but I occasionally get the use of a twin, side-by-side unit. This swapping of drives has, on occasion, been confusing, not knowing immediately why a program or the computer hangs up in mid program. Being electronically minded,

the ideal implementation would, naturally, be some sort of indication unit to show exactly which drive was being accessed. I designed, built and installed this unit and, to avoid actually modifying the computer, I built a piggy-back board.

The piggy-back board consists of a piece of Veroboard, with two rows of pins (pulled from an a.c. socket) soldered at the same spacing as a standard 14-pin d.i.l. unit. On the same board is a 14-pin d.i.l. socket, connected in parallel with the pins. In the computer, IC79 was removed, the piggy-back board replacing it, and IC79 put into the new socket, on the piggy-back board. I built the circuit shown in the top half of the diagram, on a slim piece of Vero' (it had to fit under the area below the perspex ruler), and was quite happy with it. I later thought that instead of having 4 l.e.d.s representing the four drives, why not have a digital display? This was worked out, and as it used one of the initial i.c.s, number 1 on my diagram, I added the circuitry shown in the bottom half of the drawing, thereby keeping both digital readout and discrete readout. From the piggy-back board to the indication panel, 5 connecting leads are required. These are: 0V lead, +5V lead, and the three control leads marked X, Y and Z. The supply lines are taken from pins 14 (+ve) and 7 (0V). IC1 was included, the way I devised the circuit, to minimise the loading to one extra load per output from the gates in IC79, because I am not certain as to what requirements the disc-drive requires (that is still under guarantee, whereas the computer isn't).

Malcolm C. Broughton, Liverpool.
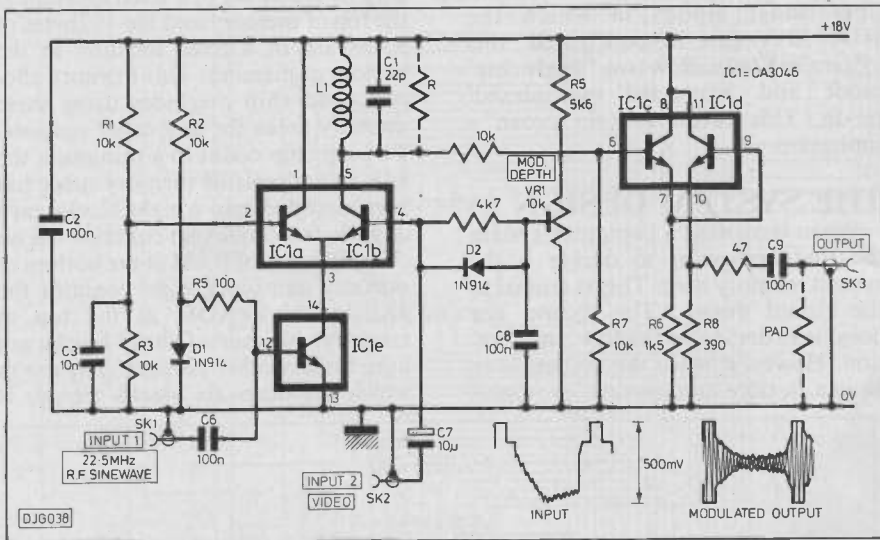
Fig. 3.1. *Mixer/multiplier*

HIGH LEVEL IC MIXER/MULTIPLIER

Low cost–high performance TV test gear

I recently required a high level mixer/multiplier for use in a TV i.f. test set. The cost of the mixer had to be kept low, but the performance had to be good. A look at the prices of most double balanced mixer/multipliers led me to consider alternatives.

The RCA CA3046 integrated circuit transistor array was eventually used in the circuit arrangement illustrated. The CA3046 can be obtained for around 70p.

In this arrangement all transistors in the array are needed, so the biassing diode D1 had to be off-chip. If the output followers are not needed then one of the base-emitter junctions can be used for D1 with the advantages of thermal coupling and tracking, but in the circuit shown, bias stability has not been any problem.
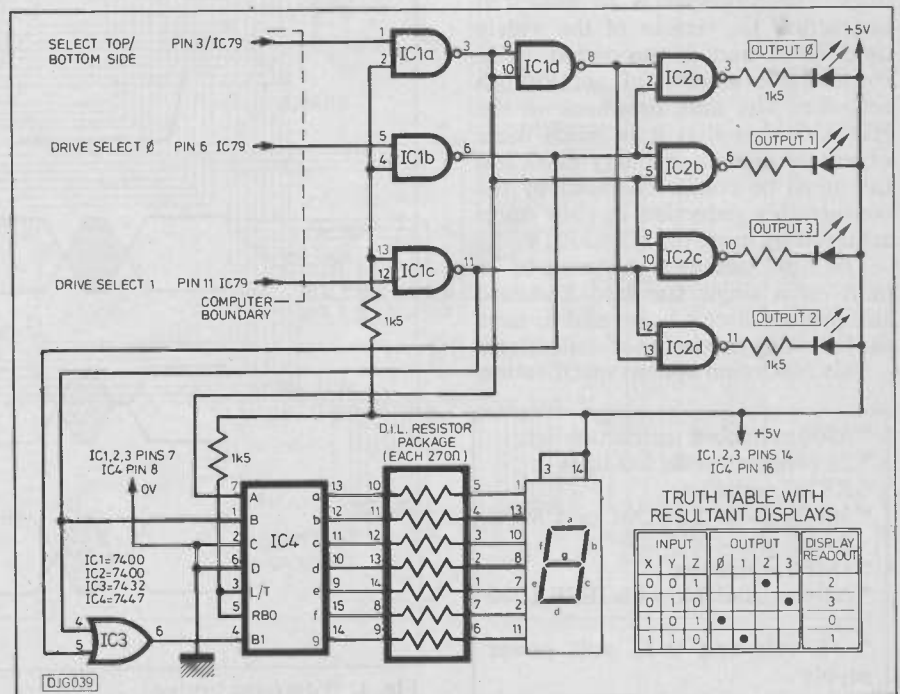
PE SBC—1 (HD63701V)

PART 1 BY NICK HAMPSHIRE

An advanced single board computer

SINGLE board computers, or SCBs, are finding an increasing number of applications in many areas, from process control to robotics. This article, the first of four, looks at the design of a flexible and versatile single board computer based on the Hitachi HD63701V single chip computer. The computer is designed to allow the user to use as many or as few of the features of the board as are required. This allows the cost of the board to be tailored to the application for which the board is intended. The design of this SBC conforms to the proposed IEEE 1000 bus standard for connecting this board to other peripheral or memory expansion boards. The adoption of the IEEE 1000 standard will considerably increase the usefulness of this SBC design.

The HD63701V single chip computer was adopted as the main processor simply because it has so many features on this single chip that the circuit can virtually be reduced to just the processor chip. The HD63701V features 4Kbytes of on chip EPROM, 192 bytes of RAM, a serial communication port and up to 29 parallel I/O lines. The processor is an advanced instruction set version of the widely used 6800 and is supported by a considerable amount of applications software. The only drawback to the HD63701V is that it is much more expensive than an ordinary 6800, but this must be counterbalanced by the considerably reduction in chip count achieved by using the HD63701V.

The SBC system is designed to be built on a single standard Eurocard size printed circuit board and to have the following maximum specifications. This maximum system specification

* 6800 enhanced instruction set
* 28 programmable I/O lines
* RS232 serial I/O
* 36Kbytes of EPROM or CMOS RAM
* 1MHz operation
* fully expandable with IEEE 1000 bus
* +5 volt and ±12 volt power supply

can easily be reduced by simply omitting certain sections of the circuit. Thus the choice of memory chips was dictated by the necessity to allow the complete interchangeability of EPROM and RAM chips using the same socket. Of the four different operational modes in which the HD63701V can be configured, this system will only allow two, 'single chip' mode and 'expanded multiplexed' mode. This is unlikely to prove a limitation.

THE SYSTEM DESIGN

When designing a computer system the first key point to decide is the system memory map. This is crucial to the circuit design. The second key point is to decide on the I/O configuration. However, since the system is to have a flexible architecture, provision must be made to allow for the easy alteration of the system memory map and I/O allocation within the limits that are possible. The HD63701V microcomputer chip imposes some limitations since the 4Kbytes of on chip EPROM are in a fixed location at the top of memory and the 192bytes of RAM are in a fixed location at the bottom of memory. This memory allocation on chip precludes using these memory areas for any other purpose. To keep chip count to a minimum the 64K of addressable memory space has been decoded into a eight blocks each of 8Kbytes. Block one contains the on chip 192bytes of RAM at the bottom of memory and block eight contains the 4Kbytes of EPROM at the top of memory. Neither of these blocks are used for any other purpose. The use to which the other six blocks are put is
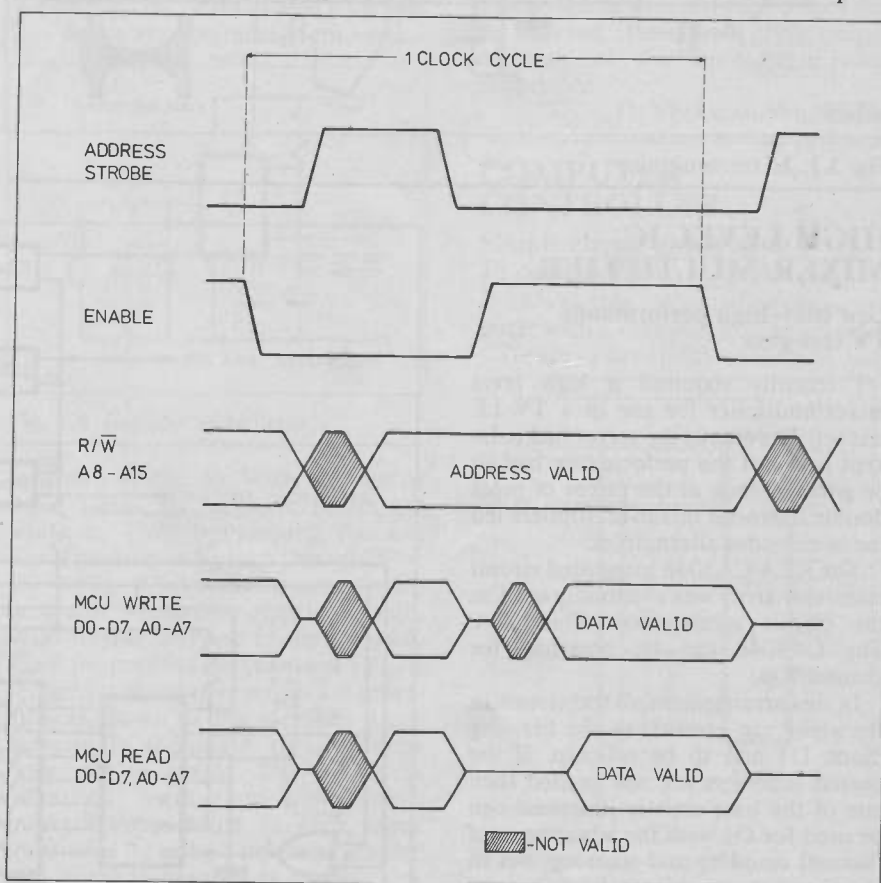
Fig. 1. *Waveform timing*
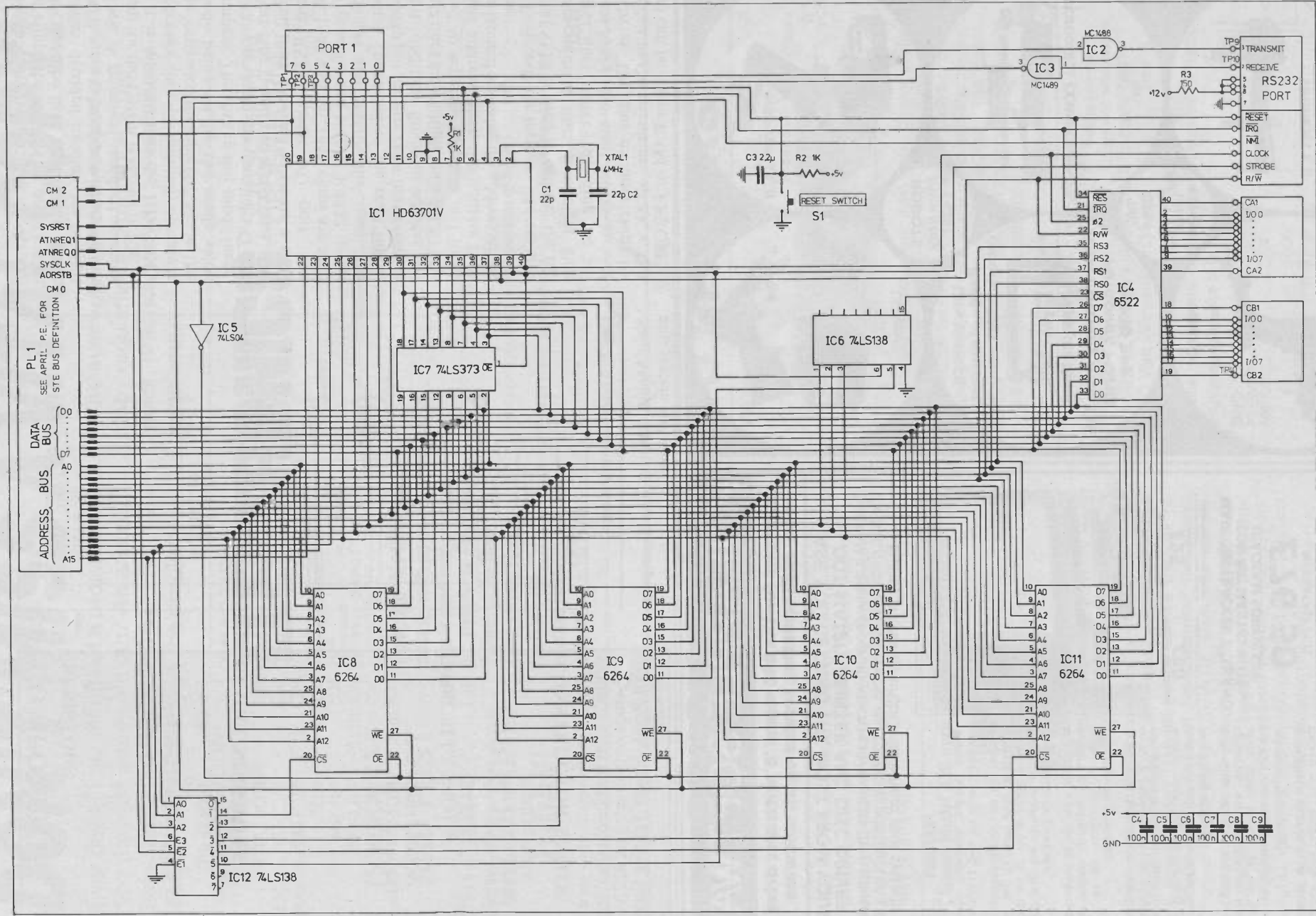
Fig. 2. *Circuit diagram of single board computer system*

selectable by jumper. The blocks can be either RAM/EPROM or I/O. One block can be used for I/O and this is further decoded to allow up to eight I/O devices to be addressed within this block. A proposed standard memory map for the system is shown in Fig. 3.

It is intended that the HD63701V processor chip will normally operate in the 'expanded multiplexed' mode, this mode being set by the mode select jumpers. The chip in this mode incorporates an eight-line parallel I/O port (Port No. 1) and two serial lines. The serial lines are used to create a standard RS232 serial I/O port. The MC1489 and MC1488 chips are used to generate the correct RS232 driver voltages and amplify the input. The switch connected to the reset line is used to put the processor into a reset or start condition. Since the address and data lines are multiplexed a 74LS373 is used to separate the data and lower eight address lines; the address lines are latched out using the address strobe line.

To decode the memory address area a 74LS138 is used to convert the top three address lines into eight chip select lines thereby dividing the address space into eight blocks each of 8Kbytes. The four memory chips included in the circuit are all 8K × 8bit and can be either RAM or EPROM.

Address	Contents
$ FFFF	4KBYTE EPROM ON PROCESSOR
$ E000	
$ DFFF	UNUSED
$ C000	UNUSED
$ BFFF	I/O EXPANSION SLOTS 1 TO 7
$ A3FF	
$ A000	I/O PORT 0
$ 9FFF	RAM/EPROM
$8000	
$ 7FFF	RAM/EPROM
$ 6000	
$ 5FFF	RAM/EPROM
$ 4000	
$ 3FFF	RAM/EPROM
$ 2000	
$ 1FFF	UNUSED
	192 BYTES RAM ON PROCESSOR
$ 0000	

Fig. 3. *System memory map*

Next Month: More circuit description and system software.

COMPONENTS . . .

RESISTORS
R1,R2	1K (2 off)
R3	150

CAPACITORS
C1,C2	22p (2 off)
C3	2μ
C4–C9	100n (6 off)

SEMICONDUCTORS
IC1	HD63701V
IC2	MC1488
IC3	MC1489
IC4	6522
IC5	74LS04
IC6,IC12	74LS138
IC7	74LS373
IC8 to IC11	HD6264 RAM or 2764 EPROM

MISCELLANEOUS
PL1	64-way Din 41612 a + c right angled
S1	P.c.b. mounting push to make

CONSTRUCTOR'S NOTE:
The microprocessor chip used in this project may be obtained from Anzac Components Ltd, 822 Yeovil Road, Slough Trading Estate, Slough.

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SPECIAL OFFER TO READERS

To coincide with our 'Solar Challenge' competition we are making a special limited offer to readers of two solar energy products from Chronar Ltd. These offers are exclusive to readers of Practical Electronics and these products are not yet available from any other source. Practical Electronics has only a limited number of these products available and this offer will expire either when our supply is sold or on May 31st 1986.

Chronar Model 330 portable solar battery charger
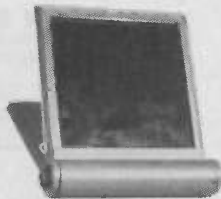
This small portable unit uses a 4" x 4" solar cell to re-charge two AA size NiCad batteries, the unit also has a direct power take-off which allows the cell to power a small radio or tape recorder, the power output of the cell is 1/3 Watt. This solar battery charger is small enough to fit in a pocket or backpack, it can be used anywhere to charge batteries for use in cassette players, radios, pen-lights, cameras, and battery powered toys. This unit will go on sale in the UK later this year.

Special PE offer price £19.95 (recommended retail price £25)

1 Watt solar panels
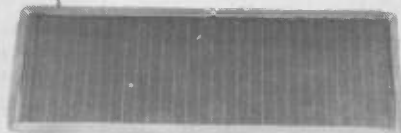
If you want to build your own solar power project these 12" x 4" amorphous silicon solar panels offer the ideal component for constructing such a project. These panels are very easily used and can be built into much larger panels if required. The panels output 1 Watt in full sun with an output of 14 volts and 50mA under load conditions.

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Qty   1 Watt solar panels at £15 each   Total
Total   Please add £1 post and packing.
I enclose cheque/postal order/money order made out to Practical Electronics to the value of £

Name ....

Address........................

....

....

Signed........................

BBC MICROFORUM

BY RAY STUART

Useful inhibitions and enhanced light-pen with visual feedback

In this month's BBC Microforum we will look at two items. The first should be of interest to anyone who has accidentally hit the break key and lost a program. I did this once and lost a day's work. I was developing some software and had not stored it on disc—so make sure that you save programs at regular intervals. Hence the development of a break key inhibit circuit.

The second subject is an enhanced lightpen that provides visual feedback allowing the operator to establish when it is in the required position.
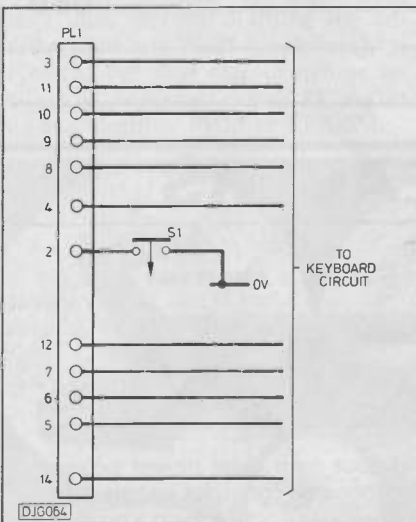
Fig. 1. *Keyboard connection details*

BREAK KEY INHIBIT

One problem experienced by users of the BBC microcomputer is accidentally hitting the break key thereby erasing the program. This may not be too disastrous if that program is stored on disc or tape, but it is still frustrating and time consuming having to reload, particularly from tape. This problem can be especially annoying in the teaching environment where children appear to be especially adept at hitting this key.

Acorn have recognised this problem and rectified it on the BBC Master series of microcomputers by fitting a mechanical locking system, but such a system is not easily fitted to the BBC B. However, it is relatively easy to fit an electrical system that can be installed
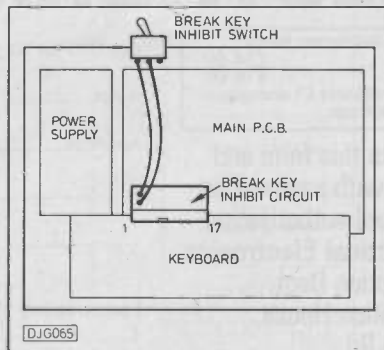
Fig. 2. *Break inhibit position*

without having to break any tracks or make any soldered joints within the BBC.

The break key is connected to the main printed circuit board, together with the others on the keyboard, by means of a 17-way ribbon cable. Examination of the keyboard circuit diagram shows that S1, the break key, is fed via pin 2 on PL1 as shown in Fig. 1. The BBC microcomputer is reset when the switch is closed.

All that is necessary in order to prevent accidental resets is to fit another switch in series with that on the keyboard. The simplest way to implement this is to fit a small stripboard in line with the ribbon cable as shown in Fig. 2. The break inhibit switch can be fitted on the back of the BBC microcomputer's case. Acorn have thoughtfully provided two suitable holes located on the left of the analogue port connector, one of which appears to have been intended for a reset switch, but never used.

The easiest way to build this circuit is to use a small piece of Veroboard and p.c.b. headers and sockets. These are available in a number of sizes, but
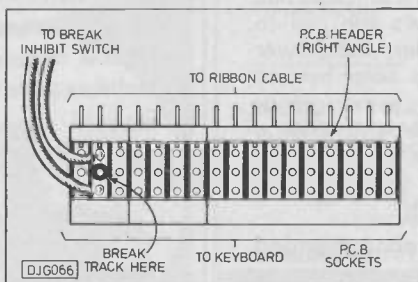
Fig. 3. *Break key inhibit circuit board*

not, however, in 17-way. The sizes available in 10, 4 and 3-way, one of each being used to produce the required 17-way.

The layout of the small piece of stripboard is shown in Fig. 3. It is only necessary to cut one track and connect the two halves together via the inhibit switch. The inhibit switch is simply left in its open-circuit state to prevent accidental resets.

ENHANCED LIGHT-PEN

Light-pens have been discussed in past issues of the BBC Microforum together with the operation of the 6845
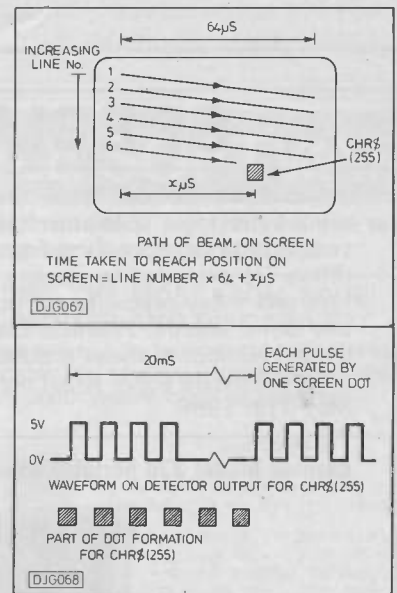
Fig. 4. *Time delays and waveforms*

CRT controller. We will not reiterate the method by which the BBC Microcomputer determines the light-pen position, however, this month's BBC Microforum we will discuss an enhanced version and describe the constructional details of the unit.

One problem associated with lightpens is that of knowing when it has been accurately positioned. Those previously described have no feedback to the operator. This can be overcome by providing an l.e.d. that is illuminated when the light sensor is activated.

The ASCII character 255 produces a square character consisting of a num-
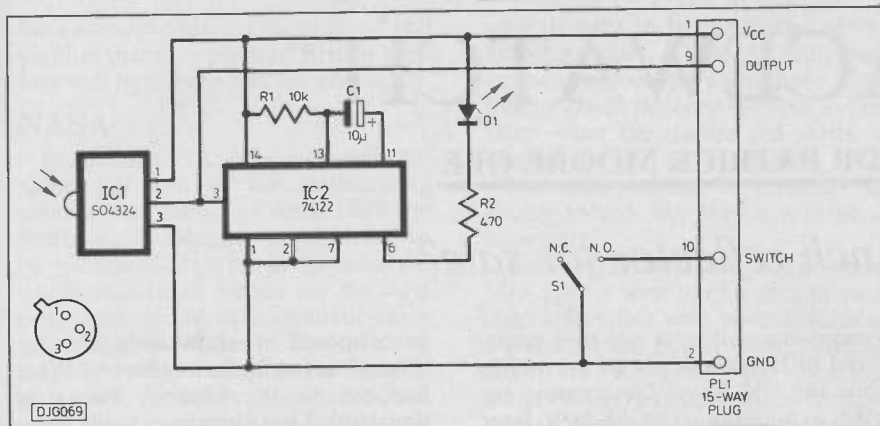
Fig. 5. *Light-pen circuit diagram*

the screen, it may be necessary to adjust the monitor brightness control for optimum performance.

SOFTWARE

The listing shown in Program 1 displays a number of small squares, numbered 1 to 6, on the screen. If the light-pen is placed over one of them, indicated by the l.e.d. being illuminated, and the microswitch operated, the square selected will change colour and its number and positional coordinates displayed. After a short delay the square will change back to its original colour ready for another square to be selected.

PROC light-pen position (Program 2) calculates the light-pen's position on the screen. The variable offset is included to compensate for time delays between a spot being displayed on the screen and the signal from the light-pen being detected. This may require adjustment for individual systems.

Next month: 32k RAM add-on

ber of small dots. If the light-pen detects this, it produces the waveform shown in Fig. 4. It can be seen that it consists of a number of short pulses that are repeated every 20ms i.e. once every frame. If this signal were used to drive the l.e.d. directly, it would hardly be visible.

This can be overcome by using the output from the detector to operate a retriggerable monostable with a time constant greater than 20ms. The circuit diagram of the light-pen is shown in Fig. 5. The sensor is the same as that used for previous light-pens, namely the SD4324.

IC2 is a monostable, type 74122, whose output pulse width is determined by the resistor-capacitor pair R1 and C1 using the following formula.

$$T_w - 0.33 \times R1 \times C1 \frac{(1 \times 0.7)}{R1}$$

The output from the 74122, pin 6, is used to directly drive the l.e.d., D1. Resistor R2 is included to limit the l.e.d. current to about 10mA.

In order to inform the BBC microcomputer when the light-pen position is to be read, switch S1 is included. This takes the form of a subminiature microswitch.

The majority of the components are mounted on a small circuit board as shown in Fig. 6. The usual practice adopted by constructors to house light-pen components is to fit them inside a ball point or felt tip pen case. After spending some time examining those available at my local W. H. Smith, much to the amusement of the staff, I found that Stabilo make an ideal unit. It is called the *Stabilo Boss 2* and it comes with a removable inner case.

Once this is removed it can be modified to carry the light-pen components. Take care when cutting through the inner case as it is full of ink which could stain clothing. The light sensor, microswitch and connecting cable should be connected to the printed circuit board as shown in Fig. 6. It should be noted that two holes are

provided on the printed circuit board to allow the connecting cable to be clamped by a cable tie.

The completed assembly can now be fitted into the modified inner case. The light sensor fits snuggly into the tip where the old felt tip was. The microswitch should be eased into the tip so that its button exits via the 3mm hole. It is then wedged into place by means of a small piece of card. Remember to pass the connecting cable through the modified end section of the inner case and the outer case before fitting the 15-way D-series plug. The inner section can now be fitted into the outer section ensuring that the l.e.d. is visible through the 3mm hole in the end section.

The light-pen can now be plugged into the BBC microcomputer's analogue port and tested by placing it over some characters on the screen, e.g. the sign-on message. The l.e.d. should light as it passes over the illuminated areas of

Programs 1 and 2. *Light-pen demonstration and light-pen position*

```
 90 A=2
100 MODE7
110 / DU23;8202;0;0;0;
120 CLS
130 PROC_heading
140 PRINTTAB(7,6);CHR$(141);CHR$(134)"    Light-pen test   ";CHR$(141);CHR$(156)
150 PRINTTAB(7,7);CHR$(141);CHR$(134)"    Light-pen test   ";CHR$(141);CHR$(156)
160 A$=CHR$(255)
170 REPEAT
180   PRINTTAB(3,20);"  ";A$;"    ";A$;"    ";A$;"   ";A$;"   ";A$;"  "
190   PRINTTAB(4,18)CHR$(130)" 1    2    3    4    5    6  "
200   PRINTTAB(9,11)CHR$(133)" SELECT  POSITION "
210   PRINTTAB(10,13)"                        "
220   PRINTTAB(10,15)"                        "
230   PROC_light_pen_position
240   / DU7
250   PRINTTAB(10,11);CHR$(133)" LIGHTPEN IS AT   "
260   PRINTTAB(10,13)CHR$(131)" X=";penx," Y=";peny
270   PRINTTAB(penx-2,20)CHR$(132)" ";CHR$(255);"  "
280   A$=INT(penx)/5
290   PRINTTAB(12,15);CHR$(129)" POSITION ";A$
300   t=TIME+300
310   REPEAT UNTIL TIME>t
320   UNTIL FALSE
360 DEFPROC_light_pen_position
370
380 LOCAL offset, width, scale
390 offset=10248 : width=40 : scale=1
400 REPEAT
410   ?&FE00=16 : hipen=?&FE01
420   ?&FE00=17 : lopen=?&FE01
430   penpos=INT((hipen*256+lopen)-offset)
440
450   peny=penpos DIV width
460   penx=INT((penpos MOD width)/scale)+1
470   X=ADVAL(0) AND 3
480   UNTIL X=2
490 ENDPROC
530 DEFPROC_heading
540
550 PRINT
560 PRINTTAB(5)" ";CHR$(148);CHR$(157)"                    ";CHR$(156)
570 PRINTTAB(5) CHR$(141);CHR$(148);CHR$(157)"  BBC Microforum    ";CHR$(156)
580 PRINTTAB(5) CHR$(141);CHR$(148);CHR$(157)"  BBC Microforum    ";CHR$(156)
590 PRINTTAB(5) " ";CHR$(148);CHR$(157)"                    ";CHR$(156)
600 ENDPROC
```

The light-pen p.c.b. is available from the PE PCB Service
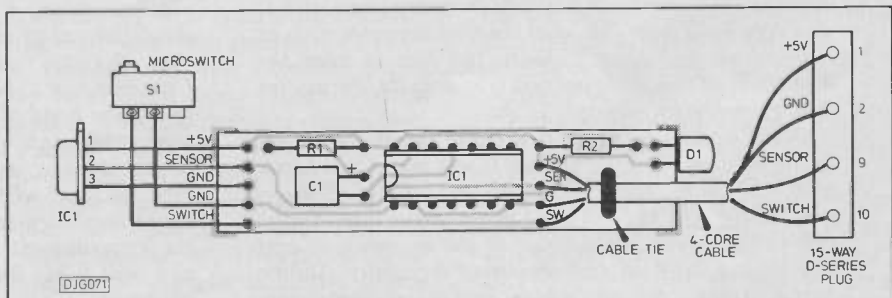
Fig. 6. *P.c.b., component and wiring details (See PE PCB Service)*

SPACEWATCH

BY DR PATRICK MOORE OBE

36 inch reflector for sale?

TURMOIL

So far as British astronomy is concerned, the whole scene is one of turmoil—because of the announcement by the S.E.R.C. that Herstmonceux Castle it to be closed down and the equipment 'disposed of'.

The Royal Greenwich Observatory was founded in 1675, with the Rev. John Flamstead as its first Director. Flamstead was subsequently created Astronomer Royal, and the post of Astronomer Royal was synonymous with that of Director of the R.G.O. until the retirement of Sir Richard Woolley sixteen years ago. Both the subsequent Astronomers Royal (Sir Martin Ryle and Sir Francis Graham Smith) have been radio astronomers, based away from the Royal Observatory; the present Director of the R.G.O. is Professor Aled Boksenberg.

The Observatory has a reputation second to none. It remained at Greenwich until observing conditions there became impossible; it was then transferred to Herstmonceux in the 1950's while the Old Royal Observatory became a museum. The 98-inch Isaac Newton reflector began its career at Herstmonceux, but was then given a new 100-inch mirror and taken to the new observatory at Las Palmas.

It is true that observing conditions at Herstmonceux cannot compare with those in the Canaries; but the R.G.O. is still the focal point of British astronomy, and to lose Herstmonceux would be a disaster in every sense of the word. What the bureaucrats do not seem to appreciate is that once an institution such as this is destroyed it can never be re-created. At Herstmonceux, new equipment is being developed (much of the research which went into the production of the CCD was done here) and there is also a large amount of theoretical work.

If Herstmonceux is closed, what happens to the equipment? How can it be 'disposed of'—how does one dispose of, say, a 36-inch reflector? What happens to the library? The time department has already virtually gone; but who produces the Nautical Almanac, founded by another Astronomer Royal, Maskelyne, more than two centuries ago? None of these questions can be easily answered. The facile comment that the responsibility for Las Palmas will be 'transferred to another university' is not in the least helpful.

It is interesting to speculate as to why the S.E.R.C. has decided to close the Castle. There seems no sense in it—in the long run it will not even save money; and in any case, comparing the cost of Herstmonceux with that of, say, a nuclear submarine can lead to only one conclusion. It is very much to be hoped that pressure will make the S.E.R.C. change its mind. The closure is scheduled for 1988; unless reason prevails, after that we will no longer

THE SKY THIS MONTH

Take your last chance of seeing Halley's Comet with binoculars or a small telescope! Our most famous cosmic visitor is now receding from both the Sun and the Earth, and is fading rapidly. On May 1st the position is RA 10h 59m, declination S.19°54', very close to the star Alkes or Alpha Crateris. Now that the comet is so much further away, its mean daily motion is very slow, and it will remain in the area of Crater and Sextans for the rest of 1986.

Of course, at the moment of perihelion (9 February) the comet was on the far side of the Sun, and unobservable from Earth. It had been planned to observe it from the Pioneer probe now orbiting Venus —but by sheer bad luck there was a violent solar eruption a few hours earlier, which resulted in the solar wind completely obliterating all signals from the spacecraft! The solar outbreak also caused one of he brightest aurorae to be seen over England in many years; it was well seen even from the southernmost counties such as Hampshire and Sussex. Since the Sun is near the minimum of its eleven-year cycle of activity, the aurora took everyone by surprise.

Of the planets, Venus is an evening object, rather low in the western sky after sunset; it sets about two hours after the Sun. Mars increases in brightness from magnitude −0·4 to −1·3 as it nears opposition, and is prominent in the early hours of the morning; it and Jupiter are both in the region of Aquarius. Saturn comes to opposition on 28 May, and is therefore visible
all through the hours of darkness. The magnitude is 0·2, and the ring system is wide open, so that the planet is a glorious sight even in a small telescope. (Binoculars will not show the rings, though a powerful pair will be enough to show that there is something unusual about Saturn's shape.)

The Aquarid meteor shower lasts for the first week of May, but is not spectacular. The Moon is new on the 8th and full on the 23rd.

The evening sky is now dominated by the spring groups, notably Leo and Virgo; the Great Bear is near the zenith, which means that the W of Cassiopeia is low down in the north. (Cassiopeia and the Bear lie on opposite sides of the Pole Star, and at about the same distance from it.) The brilliant orange Arcturus is high in the east; the twins, Castor and Pollux, may still be seen in the west, though they set around midnight. In the low south, look for the fairly prominent little quadrilateral of stars making up Corvus (the Crow); west of Corvus is Crater (the Cup), where Halley's Comet is now to be found. Late in the evening we start to see the head of the Scorpion, with the brilliant red supergiant Antares; the 'sting' only just rises from South England, and not at all from Scotland. This is a pity, because when high up, as seen from southern countries, Scorpius is one of the most magnificent of all the constellations. As well as its bright stars, it contains rich star-fields and some bright open and globular clusters.

have an active Royal Observatory, and another priceless piece of British heritage will have been lost for ever.

NASA

In America, NASA has now selected names for two of the forthcoming planetary missions. In April 1988 the Venus Radar Mapper is scheduled to be launched; its aim is to map the whole surface of Venus for the first time, making use of a synthetic-aperture radar instrument. The resulting maps should be adequate to identify geological processes; the probe will approach Venus to within 250km, and will have an orbital period of 3 hours. Its new official name is Magellan.

In August 1990 comes Mars Observer, formerly known as the Mars Geoscience/Climatology Orbiter. It should arrive at Mars in August 1991, and will map the Martian surface, mainly to investigate mineralogical characteristics and the various climatic variations. Of course, both these probes were due to be launched from the Space Shuttle, and as yet it is too early to say whether the Shuttle programme will be back on schedule by then; one can only hope so.

THE MOST REMOTE QUASARS

Quasars are believed to be the most distant of all known objects, and are now thought to be the nuclei of very active galaxies. There are still some eminent astronomers who have strong doubts about the conventional explanation—that the quasar red shifts are 'cosmological', i.e. Doppler effects —and the problem is certainly not finally solved; but this is a minority view only.

Because quasars are so powerful, they can be seen over a greater range than is possible with normal galaxies. Up to now the holder of the 'distance record' is PKS 2000–330, discovered at the Parkes radio astronomy observatory in Australia. It has a red shift of 3·78, corresponding to a distance of perhaps 13,000 million light-years.

Also using results from the Parkes telescope, J. S. Dunlop and his colleagues at Edinburgh have now identified another very remote quasar, PKS 1351–018, which has a red shift of 3·72, second only to PKS 2000–330. But it has taken a great deal of time to find a quasar as far away as this, and something very interesting has come to light. Though over seventy known quasars have red shifts of over 3·0, there seems to be a virtual cut-off at 3·8.

Why? Well, we know of course that we are seeing a very remote object not as it is now, but as it used to be a long time ago; assuming that the conventional explanation is correct, we are seeing PKS 2000–330 as it was 13,000 million years in the past. The rule is that the greater the distance, the greater the red shift, and if this holds good we will come to a distance at which an object is receding at the speed of light—in which case we will be unable to see it, and we will have reached the boundary of the observable universe, though not necessarily of the universe itself. This critical distance seems to be between 15,000 and 20,000 million light-years, probably closer to the lower figure.

POSSIBILITY

If there are no quasars further away than 13,000 million light-years, as now seems to be a distinct possibility, we can only assume that no quasars were formed in the very early part of the existence of the universe. We cannot say the same about normal galaxies, of course, but we need extra optical and radio techniques before we have a chance of picking up galaxies at so great a range.

Space research methods seem to hold out the best hopes of penetrating so far; the Hubble Telescope should be invaluable. But we also need detectors, based on electronic techniques; and this is an extra reason why it seems so short-sighted to close an institution such as the R.G.O., where precisely this kind of research is being carried on. **PE**

REGULAR FEATURE

THE LEADING EDGE

BY BARRY FOX

The technology behind the technology and things to come

At a recent Digital Information Exchange seminar, part-sponsored by Sony to spread the digital word, Dave Parker of the Department of Acoustics at Salford University and Dr. Trevor Lamb of the Department of Physiology told how they were using cheap Sony PCM processors to record laboratory results which would normally be captured by an industrial data recorder. Parker has modified a Sony PCM processor and domestic video recorder, with additional coupling capacitors, so that it can record signals down to a frequency of below 0·06Hz. Parker uses the system, costing under £2,000, to log explosions, which require accurate response over the range of 0·1Hz to 15kHz. The wide dynamic range of this digital system, makes it able to handle both very quiet and very loud sounds, so it is ideal for monitoring blast noise propagation.

Trevor Lamb uses a similar system to record the very small electrical output from rods and cones taken from a salamander's eye. The tissue is held in saline, exposed to light and the response signals converted into digital code for recording onto domestic video tape. At York University, David Mallam is using a domestic digital processor to record the output of a digital music synthesiser which the university's electronic music studio has built. This has a 24-bit design, which enables it to mix up to 48 separate 16-bit signals without degrading the output signal to below 16-bit standard. Mallam's processor is capable of handling 10 million instructions per second.

Perhaps most interesting, York is now using video technology cassettes to record large quantities of computer data at very low cost. A domestic video cassette is used as a bulk store for the output of a DEC PD–11. A single £5 tape can store 40 gigabits of data, which is equivalent to 5 gigabytes or 5000 million text characters. **PE**

THERMOCOUPLE INTERFACE FOR DVM

BY G. J. PHILLIPS B.Sc. C.Eng. MIEE

Transforms any DVM into a digital thermometer

SIMPLY plug the unit into a d.v.m. set to mV, position the thermocouple junction on the surface whose temperature is required and the display shows degrees C directly (×10). The unit will cater for temperatures in the range −100 to 800 deg. C. No calibration is required.

THERMOCOUPLES

The number of free electrons in a metal is dependent upon its type and upon its temperature. If two dissimilar metals are in contact, a potential difference exists between them, albeit very small. This voltage increases with temperature and with certain combinations of metals it can be shown to be reasonably linear with temperature. The joining of two dissimilar metal wires constitutes a thermocouple junction. Table 1 shows the theoretical e.m.f. that exists between various combinations of metals per degree of C.

When an attempt is made to measure this thermocouple e.m.f. with a d.v.m., however, the reading is nowhere near the theoretical value. This is because other thermocouples are created where the copper d.v.m. leads connect to the metal wires and the e.m.f.s generated at these junctions partly cancel the main junction e.m.f.

In order to make understanding easier, let us consider the most common thermocouple, Copper-constantan (Cu-Con). Constantan is an alloy (mixture) of copper and nickel and a Cu-Con thermocouple gives an e.m.f. of approx. 40µV per deg. C. When we connect a d.v.m. to a Cu-Con thermocouple we see that a second junction, Con-Cu, is created where one of the d.v.m. leads connects to the constantan wire (Fig. 1). This junction will also give 40µV per degree C so that if both junctions are at the same temperature, the d.v.m. will read zero volts. If the main Cu-Con junction is taken to a different temperature, the d.v.m. will read a voltage equal to 40µV times the temperature difference between the two junctions.

Suppose that we want to make a thermometer to measure the tempera-

ture of an oven and we place the main Cu-Con junction inside the oven and bring the wires out to a d.v.m. The display will read the difference between room temperature and the oven. This may be as accurate as we need, but consider what happens on a cold day and your central heating has just switched on. Room temperature may be 10 degrees lower than normal which will give the impression that the oven is 10 degrees hotter than it actually is.

COLD JUNCTION COMPENSATION

If an absolute reading in degrees C is required, the junction outside the oven could be placed in a container of melting ice which will be at 0 deg. C. The display reading in µV is then divided by 40 to give deg. C. Messing around with melting ice is unpractical and a more convenient method of "cold junction compensation (CJC)" is required. If the main thermocouple is always required to record temperatures above the maximum room temperature then the cold junction may be placed in a small heated cavity whose temperature is kept constant at say 40 deg. C. Some method of measuring the cavity's temperature will be required however . . . touche! A semiconductor junction is quite a good indicator of modest temperatures, giving a decrease in forward drop of about 2·5mV per degree C rise. Temperature controlled cavities using a semiconductor junction as the sensor have been used for many years for CJC. Peltier devices are sometimes used to cool CJC cavi-

ties to 0 deg. C, provided the room temperature never falls below freezing, otherwise the cavity would have to be heated (actually a Peltier device can do this if the current is reversed).

A more modern method of CJC is to measure ambient using a semiconductor junction, and derive a voltage which exactly matches the cold junction thermocouple voltage. This voltage is then added in series so as to add the ambient temperature to the display reading. The semiconductor junction should be mounted as close as possible to the cold junction so as to track its temperature.

In this project, use is made of the AD595 integrated circuit which comprises a type-K (nickel Cr-Nickel Al) thermocouple amplifier with integral CJC. It gives an output of 10mV per deg. C. The unit requires no calibration as this is done by the manufacturer of the AD595. The d.v.m. then reads degrees C direct without any scaling factors (apart from the decimal point). Type K thermocouples are capable of measuring from −100 to +1000 deg. C,

COMPONENTS . . .

CAPACITOR
1µ 16V electrolytic

SEMICONDUCTOR
AD595

MISCELLANEOUS
Type-K thermocouple; plastic case; switch; PP3 battery; battery connector; 4mm terminals (2 off); p.c.b. PE112.

however, the maximum upper limit will be governed by the battery voltage. A 9V battery will limit operation to approx. 750 to 800 deg. C. The p.c.b. is fitted with two 4mm terminals set $\frac{3}{4}$ inch apart to enable the unit to be plugged directly into most d.v.m.'s.

The unit is housed in a smart plastic potting box.

CONSTRUCTION

In order to fit the two 4mm terminals to the p.c.b. 11mm must be cut from the hexagonal section. The 4mm terminals already have one hole drilled in the hexagonal section; a second hole must be drilled 8mm from the first. Both holes are then tapped M3 and secured to the component side of the p.c.b. with four M3 × 6mm screws. If you do not have M3 taps, the terminals may be fitted to the p.c.b. using short lengths of heavy gauge copper wire.

The type K thermocouple is soldered next (the white insulated wire is +ve). Use thin twine to anchor the thermocouple to the p.c.b. to prevent the wires from shearing at the p.c.b. holes. IC1, C1 and the wires to the switch and battery holder are then soldered in place. A cover is required which can be made by drawing around the shape of the box onto plastic sheet or Paxolin. After cutting out the cover, clamp it to the box and drill a 4mm clear hole through each lug of the box and cover so that they may be fastened together with 4mm screws. Cut out a hole in the cover for the switch, taking care to position the switch so that it does not foul with the battery when it is in position in the box.
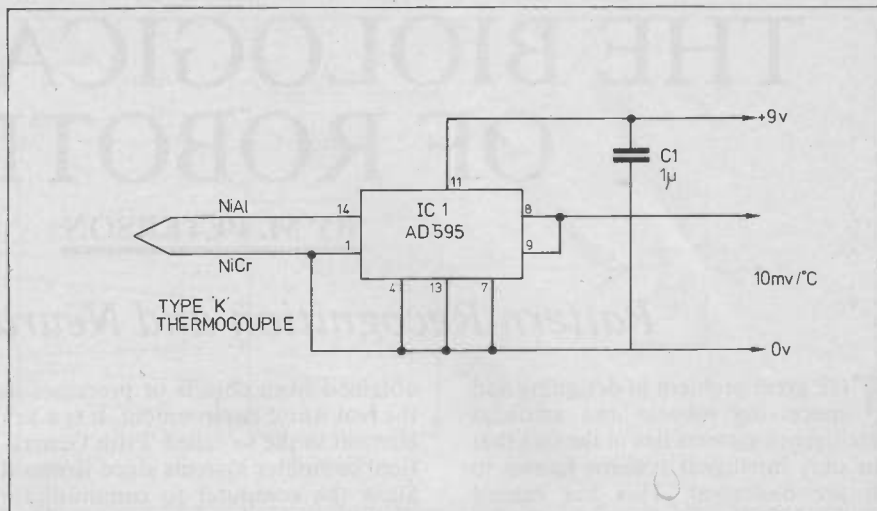
Fig. 1. *Circuit diagram*
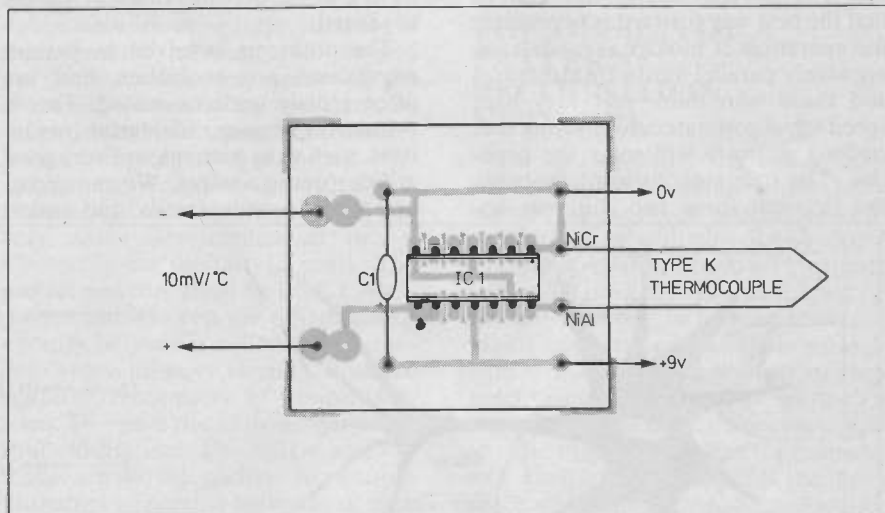
Fig. 2. *P.c.b. layout details*
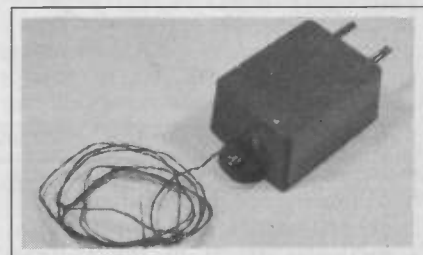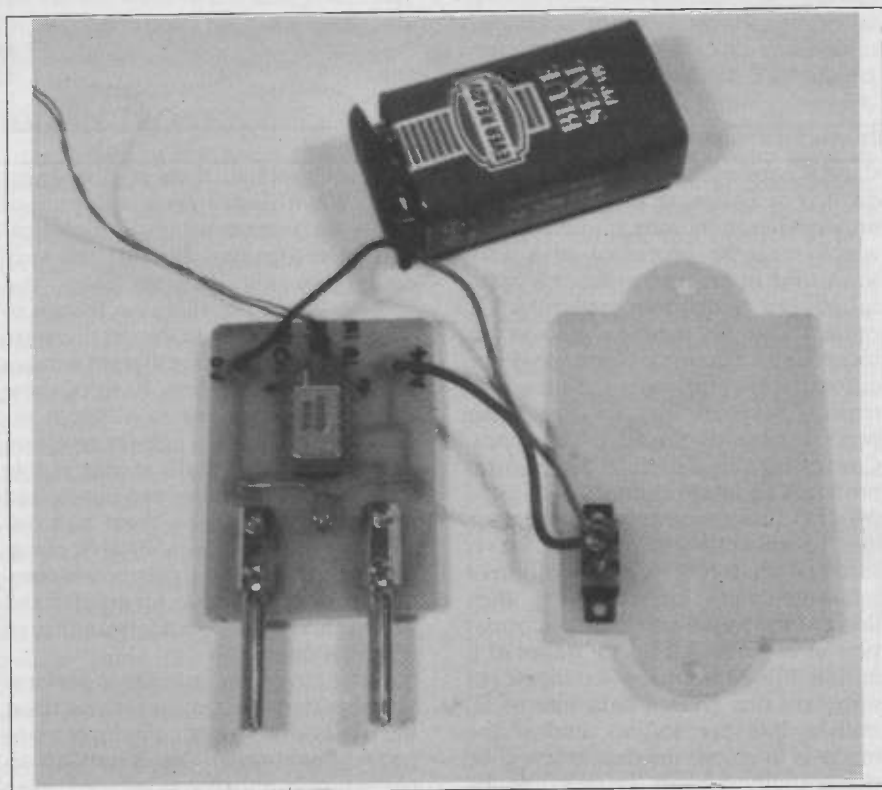
The thermocouple is passed through the small hole in the box and then the two 4mm terminals are passed through the holes in the opposite end of the box. The p.c.b. is slowly lowered into place whilst pulling the thermocouple wire through the small hole. A piece of foam rubber is then fitted on top of the p.c.b. to prevent the battery case from shorting out the p.c.b. components and to stop everything from rattling around inside the box. The cover is then secured with two 4mm nuts and bolts.

HOW IT WORKS

The AD595 does all the work. It accepts the signal from the type-K thermocouple and converts it to 10mV per degree C.   **PE**

THE BIOLOGICAL BASIS OF ROBOTICS

BY M. PETERSON

Pattern Recognition and Neural Networks

THE great problem in designing and conceiving robotic and artificial intelligence systems lies in the fact that the only intelligent systems known to us are biological. This has caused artificial intelligence researchers to fall into two groups—those who believe that the best way forward is to emulate the operation of biological models using highly parallel hardware structures and those who think that very high speed serial computers supporting specialised software will solve the problem. The true path forward probably lies between these two different approaches. Different aspects of the artificial intelligence problem require different approaches. This article looks at a particular aspect of the artificial intelligence problem, pattern recognition, and how specialised hardware systems which emulate the neural networks found in the brain can be used to solve this problem.

Pattern recognition concerns the labelling of well defined and recognisable images, sounds or measurements obtained from objects or processes in the real world environment. It is a key element in the so called 'Fifth Generation' computer systems since it would allow the computer to communicate directly with the real world without having to transfer information via the keyboard.

The problems involved in pattern recognition are enormous, and are often grossly underestimated. This is primarily because biological organisms, such as us humans, are very good at interpreting images. We can recognise faces, sounds, smells, and understand scenes, without knowing how we do it. For designers of machines the problem lies in the vast amount of data which must be processed in a very short time in order to produce a pratical pattern recognition system. A TV camera can be used to convert an image into electronic form, and the output signal represents the image intensity, scanned line by line. This process takes about 40 milliseconds. Converting this data into digital form produces an image comprised of some 250,000 image points or pixels, each having an intensity value. If it is assumed that ther are 256 different intensity values for each pixel, then this gives the total amount of information in any one TV image frame of 2 million bits At normal TV image scanning rate this gives a data rate of 50 million bits per second, and if the image is in colour the data rate will be substantially higher. Images can be binarised using a threshold value such that each pixel has only two intensity values, black or white. This reduces the data rate but it is still a very hefty 6·25 million bits per second. Given that a medium power computer will perform about 5 million instructions per second and a super computer only 200 million per second and that several hundred instructions will be required to process each bit of data, it can be seen that they cannot keep pace with the data rate of images at TV picture resolution.

Pattern recognition using electronic equipment is, therefore, a much more complex problem than at first imagined. When describing a sequence of video, we humans using our biological pattern recognition system, can very easily pick out different faces and objects. We can do this even though in terms of data being collected there are probably millions of different images of, say, a person's face. Each of these images is unique due to different expressions, changes in lighting, position and orientation. Yet the human is able to take in the images of two people and immediately recognise them and distinguish between them. Pattern recognition is, therefore, an extremely complex task which we take for granted and yet have very little understanding of how it is done.

As we have seen, in order to perform visual pattern recognition in real time, the use of even super computers using conventional serial Von Neumann architecture is unlikely to succeed, even

Fig. 1. *A neuron and the McColloch and Pitts neuron model*

$$R=1 \text{ if } \underline{W}.\underline{I} > T \text{ else } R=0$$

INPUT $\underline{I}$ WEIGHT $\underline{W}$ SUMMATION   THRESHOLD T
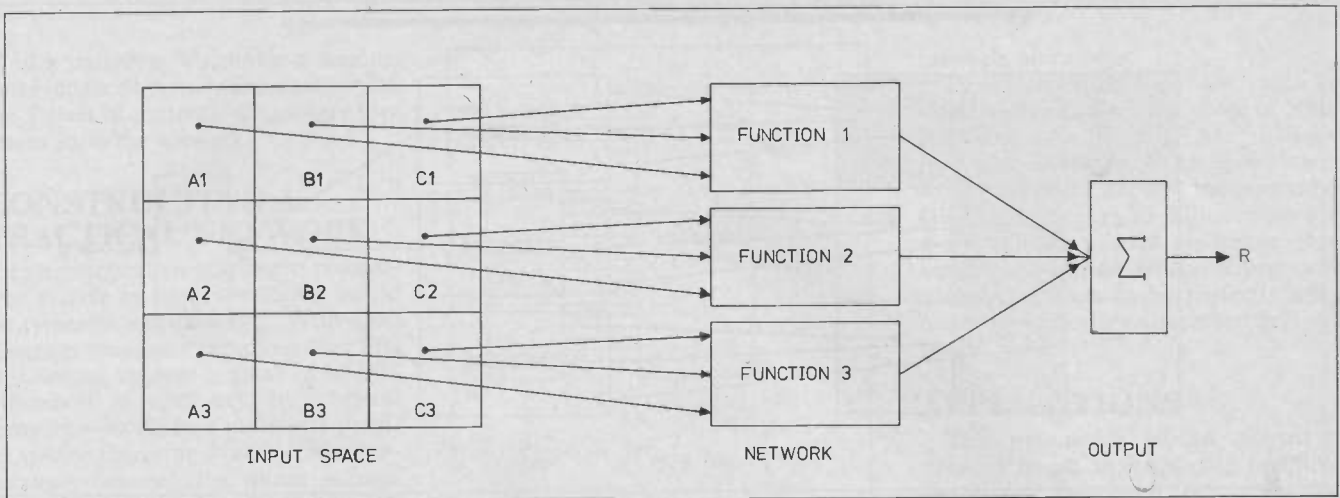
Fig. 2. *A simple 3 processor network*

given the development of optical computer systems operating with instruction times of a few femtoseconds. The problem requires a parallel computing solution whereby the image is split into many small images each of which is being analysed by a processing unit. This is, of course, exactly how the brain works. The brain is composed of a vast interconnecting network of some 10^{10} nerve cells (or neurons), some of which have up to 5000 inputs. The structure of the brain, given our present knowledge, defies any deep analysis, however, the structure of an individual neuron has been studied in depth. Consequently various mathematical and electronic models of neurons have been proposed. One of the earliest was proposed in 1944 by McCulloch and Pitts and formed the basis of some of the earliest work in learning machines, the percepterons. This model is shown in Fig. 1.

BRAIN-WORK

Our study of the brain and how it works has clearly shown that it is not a Von Neumann structure. There is no central processing unit or specialised memory area where data is stored in the manner of a computer data base. The brain instead is structured as a distributed parallel processor where a large number of neurons within a defined functional area of the brain are processing samples of data simultaneously. The neurons are reacting to stimuli, and then generating responses which are passed to subsequent neurons, they are not doing this as a result of preprogrammed instructions but rather by adaptation due to previous exposure to stimuli. Neurons pass messages to each other using electrical pulses. These can be measured and recorded and much research has been done on behaviour of neurons. Using this knowledge, electronic models of neurons can be constructed using binary input and output. Constructing a

neural network using large numbers of these electronic neurons is still beyond our ability. However, some of the properties of neural networks can be utilised to construct parallel processors for pattern recognition purposes.

A pattern recognition project which is showing considerable potential has been under development at Brunel University for the last 15 years. The project was conceived by Prof. I. Aleksander who noticed the functional similarity between a neuron and a random access memory element. Both are adaptive recognisers of simple patterns. This gave rise to investigation by Prof. Aleksander, Dr. Wilkie and Dr. Stoneham of the pattern recognition properties of parallel networks of such elements, loosely related to their biological counterparts. The work has proceeded steadily over the years and has recently given rise to some commercial visual pattern recognition equipment of considerable potential. The project is currently under the leadership of Dr. J. Stoneham of the Department of Electronics at Brunel. The primary objective of the work at Brunel is to develop a processing architecture which is suitable and capable of performing pattern recognition. The networks have, therefore, been tailored towards this end, however, they have demonstrated properties and behaviour which does not throw some light on the mechanisms of intelligent behaviour in animals.

THE DESIGN OF A PATTERN RECOGNITION NETWORK

The Brunel University design consists of a self-adapting single layer learning network of processors constructed using ordinary RAM chips. The input is derived from a TV camera (a parallel project at Brunel funded by British Telecom is looking at voice input) and reduced to a binary image with a 512×512 pixel resolution, each pixel being either black or white. To explain how the system works it is best to reduce the resolution of the image to 3×3. Each processor samples the input space where the image is stored and in the example three processors are used each sampling three pixels, this is shown in Fig. 2. The processors are simply three eight bit random access memories, each pixel being connected to one of the address lines of its sampling processor. Each memory has a single output line which is fed to a summation circuit. This summation circuit will produce the correct output only when it recognises an input pattern. Since the system is designed to be a self-adapting learning network it has to be trained. Training is done by first clearing the memory and setting all cells to zero. An image is then input into the system and the system trained to recognise this image by setting the data input line high. The result of
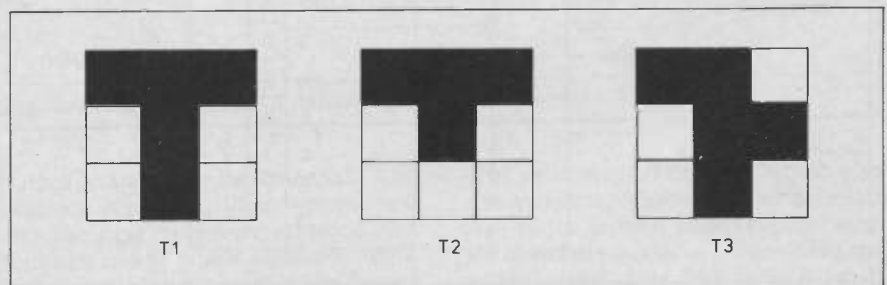
Fig. 3. *Variation of a T-pattern input*
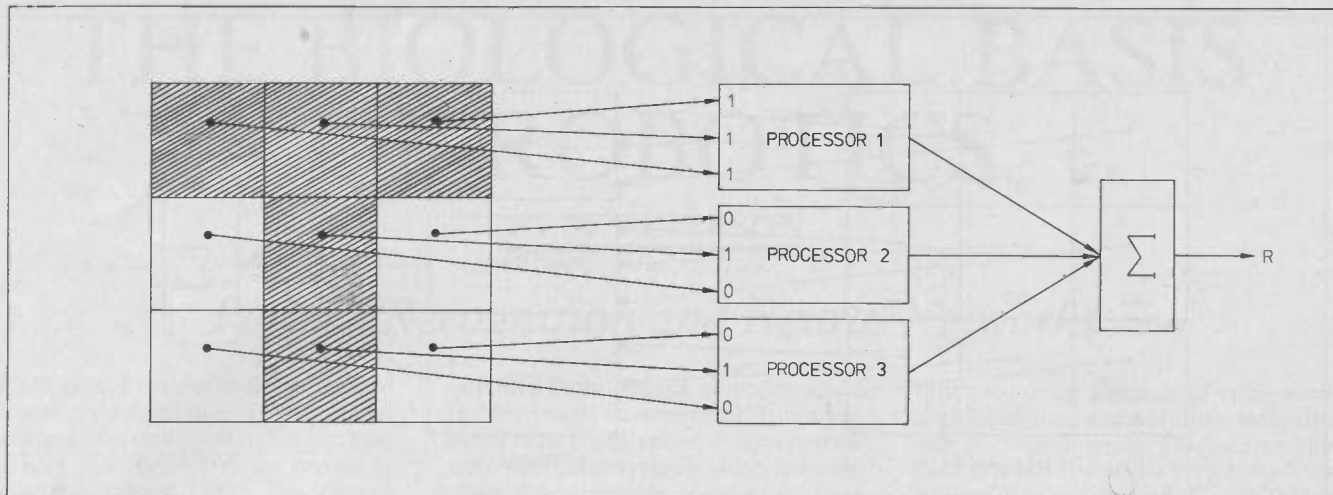
Fig. 4. *Inputting a pattern to a simple network*

setting the data input line high is that one of the eight cells in each processor is set high, this cell corresponds to the pattern on the three address lines fed from the image input. The data output line on each processor will now only be high when the input image it receives is identical to the image on which it was trained.

HOW THE NETWORK WORKS

To understand how a network like the one described above can be trained to recognise patterns; it is necessary to look at the logic involved in the training and recognition process. Using the 3×3 resolution network it can be trained to recognise simple characters like the three variations of the letter T shown in Fig. 3. The pattern is input to the network as shown in Fig. 4 and it is required that each function respond with a logical 1, the functions for the first T in Fig. 3 are:
$F1 = A1.B1.C1$
$F2 = \overline{A2}.B2.\overline{C2}$
$F3 = \overline{A3}.B3.\overline{C3}$

Each of these functions are combinational logic operators, with the n-tuple samples being minterms of the appro-
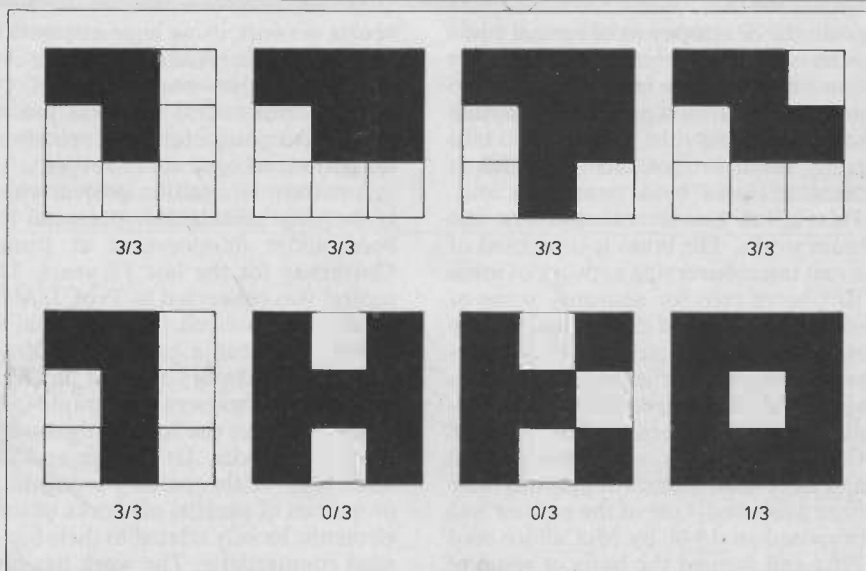
Fig. 5. *Range of input patterns and their responses to a trained simple network*

priate functions. If the network is trained on the second T in Fig. 3 then functions 1 and 2 remain the same but function 3 changes to become:
$F3 = \overline{A3}.B3.\overline{C3} + \overline{A3}.\overline{B3}.\overline{C3}$

If the third T is used then the functions change again after the training sequence:

$F1 = A1.B1.C1 + A1.B1.\overline{C1}$
$F2 = \overline{A2}.B2.\overline{C2} + \overline{A2}.B2.C2$
$F3 = \overline{A3}.B3.\overline{C3} + \overline{A3}.\overline{B3}.C3 + \overline{A3}.\overline{B3}.\overline{C3}$

The network is now trained to recognise any of these three variations on the letter T with each function producing a logical 1 output. In biological terms each function is the equivalent of a neuron, the neuron will only fire on its output when its inputs correspond to a certain pattern. A numerical response is obtained by summing the outputs of the functions. In any of the three training patterns in Fig. 3 the output value will be 3.

Besides recognising patterns on which it was trained the network will now also produce responses from patterns which have a partial similarity to the training patterns. Some examples of other patterns and their function summation values are shown in Fig. 5. These patterns show that the network is now able to classify images into groups, only those patterns using this training which contain T-like components will obtain scores of 3. The H and
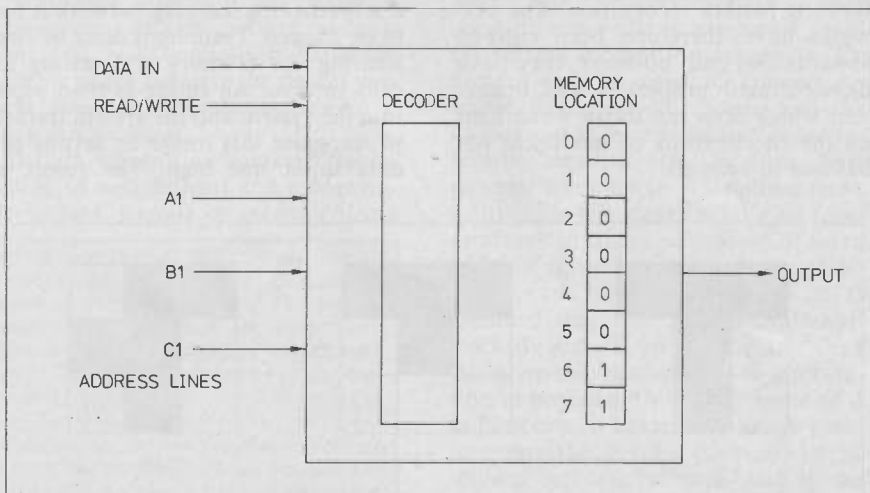
Fig. 6. *3 input RAM chip processor*

O like patterns, which to a human observer are obviously not members of the T class of patterns, all get very low scores from the network.

CONSTRUCTING A PRACTICAL NETWORK

In a practical visual pattern recognition system an input resolution would be typically 512×512 bits. With each function processor sampling four bits this would require a total of 65,536 processors in each net. In practical terms this would be a massively parallel system requiring over 250,000 connections between the image storage area and the processors. A system like this would be very difficult if not impossible to construct. However, by sacrificing some of the system's parellelism it is quite easy to construct such a network using cheap and easily available LSI memory chips. The individual processor functions can be simply programmed into the memory circuits. Using the function F1 from the letter T detector, this function will produce a logical 1 output when the three input is either 1 1 1 or 1 1 0. A RAM chip with three address lines can be used as the processor, each address line being connected to an image detector point, this RAM will have 8 memory locations as shown in Fig. 6. If the memory is initial cleared and then set into the write mode and the three function inputs (address lines) set to 1 1 1 then a logical 1 will be written into memory location 7. Similarly when the three function inputs 1 1 0 are applied then a 1 is written into location 6. At the end of the teaching session memory is set to read and the data applied to the address lines now accesses the stored information which then appears on the output line. Using the training just given the memory will only ouput a 1 when the inputs are either 1 1 1 or 1 1 0, all other inputs will produce a 0 output. The input/output behaviour of this memory cell processor is identical to the function F1, and the memory is acting as a Boolean logical operator.

The use of memory circuits as Boolean logical operators does not, of course, involve the storage of an input image. In fact, the samples of the input image are never stored. What is stored is the response by each processor to these samples. The input data only stimulates the functions. Thus the size of memory required is only dependent on the number of sample points in the image and does not vary with the number of training patterns used to set up the network. It is the contents of the memory, and hence the functions of the processors, which change. These ultimately stabilise with continued training.

The small memory units required for each processor can be obtained by
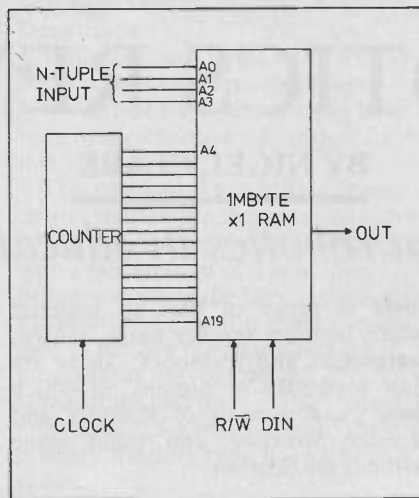
Fig. 7. *Address field division in a RAM based network*

partitioning the address field of the chip into sample inputs and function addresses. This trade off between the ideal parallel structure and more serial structure is necessary in order to reduce the number of connections between the processors and the image input store. An example of how this division of address field can be done is shown in Fig. 7. The first four address lines receive samples from the image, the remaining address lines are used as function addresses and are driven from a counter which is synchronised to the image input circuitry. When the first sample is input the counter is set to zero and a unique block of memory accessed. This memory block constitutes the first processor. If the output from this processor is a 1 then the

function processors.

The access time for RAM chips is sufficiently small (in the order of 50ns per bit) that to access all 65,536 function processors on a 1megabit chip would only take about 4 milliseconds. Given that it takes 25 milliseconds for a TV camera to grab an image, this serial organisation within a practical network appears to be perfectly adequate to perform pattern recognition in real time.

APPLICATIONS

The principles of an adaptive network based on RAM chip function processors has been developed by Brunel into a pattern recognition machine called a WISARD. This machine proved to have outstanding pattern recognition capabilities and could faultlessly distinguish between a face from a group of sixteen different faces. It performs this recognition after suitable training irrespective of the facial expressions and orientation of the subject's face. The WISARD machine has since been converted into a commercial device by Computer Recognition Systems and is being sold to companies interested in solving automated vision problems, such as product inspection, security, and robot vision.

Current research is looking at ways of extending the system, including multiple layer networks. One area of particular interest is the use of feedback. This should give WISARD the ability to identify sequences of images and to associate images with a proto-
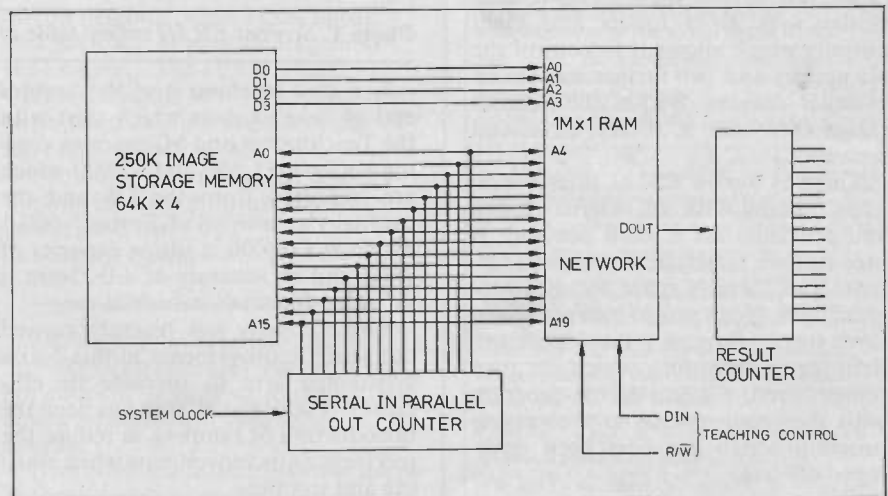
Fig. 8. *Block diagram of a pattern recognition system*

output counter is incremented. The function counter is then incremented and the next processor accessed and four new image points accessed. Again if the output is positive then the output counter is incremented. With each function having four inputs a 1 megabit chip can accommodate 65,535

type or concept. Feedback would also allow objects to be tracked in a similar way to the human visual system, with the discriminator network covering the whole visual area but with a small steerable high resolution region. This could allow the machine to locate and identify areas of visual interest. **PE**

ROBOTICS REVIEW

BY NIGEL CLARK

Our regular look at robotics in education and industry

THERE is little surprise when a new small robot from Japan, the United States or Britain is announced. Indeed it is surprising in view of their domination of the large industrial market that there are not more from Japan or the US.

However, a British company which began by importing American machines has discovered an unlikely source in the Middle East—Israel to be precise. Syke Instrumentation of Hampshire is importing the Scorbot ER III made by Eshed Robotec of Tel Aviv.

It is a standard articulated arm with five axes plus a gripper. Powered by d.c. servos, transmission is provided by toothed belts. It can lift 1kg with a repeatability of 0·5mm. The motors work under closed loop control and feedback is provided by optical encoders. In addition the motors stop automatically when an obstacle is struck and the gripper can sense objects and measure them.

The waist can move through 340 degrees, the shoulder ±85 degrees, elbow ±150 degrees, wrist pitch ±150 degrees and unlimited roll. Maximum reach is 610mm.

Scorbot comes with its own controller with eight inputs and eight outputs which allows it to control the six motors and two further motors on external devices. Within the Scorbot range there are a rotary table and conveyor.

There is also a RS232 interface to allow linking with an external micro and provision for a teach pendant. It uses its own language, known as Scorbase, and there is space for 400 program lines. It can accept instructions in three forms, through a teach pendant, defining the positions which are then remembered, a menu-driven program with the robot on-line or a complete program which has first been developed off-line.

ACCESSORIES

Other accessories included in the range are a motor kit which can operate other equipment and a laboratory experiment set.

The machine is being aimed at the education market and costs about £2,800, the accessories being extra. It forms the basis for what the makers call a complete training program and there is range of back-up material which includes teacher packs, videos, workbooks and textbooks. There are four textbooks at present, of which two, *Fundamentals of Robotics* and *Robotic Structure*, can stand alone without the Scorbot.

Photo 1. *Scorbot ER III rotary table and conveyor*

The new machine is at the bottom end of Syke's robots which start with the Teachmover and Minimover, costing between £1,500 and £2,000 which are imported from the US and the company's own SYKErobot 600-5 which at £16,000, a lifting capacity of 2·5kg and an accuracy of ±0·25mm is intended for small industrial use.

The company has recently carried out some improvements to this 5-axis articulated arm to increase its efficiency. The major change has been the introduction of ramping to reduce the jerkiness of its movements when starting and stopping.

Milton Bradley's Robotix kits have proved so popular that additions have been made to the range. Allowing for the facts that the kits are intended as toys, rather than any serious attempts to be educational or practical, and that it is not possible for sequences to be stored and played back they still provide the possibility for experimentation and the use of imagination to make interesting mobiles.

The four kits start with Tyrannix with one motor, a power droid and a simple switch controller and plastic components to make a movable device with a gripper for about £25. Bront at £40 has 2 motors with switch control and pieces for a crawling robot.

At the top of the range is Argus which contains the parts to make a dynosaur-type model on wheels with a gripper. It has four motors with control from a five channel switch console, all for a price of about £70.

MAJOR ADDITION

One of the major additions to the range has been a four-speed motor and two of these are featured in the Boltar which also includes a new linear drive and a new mechanism which allows the models to walk on four or six legs or drive on four or six wheels.

To help the imaginative robot builder develop other models it is also possible to buy expansion kits and extra motors.

Low-cost kits and robot arms are being used as the basis for courses in control technology being provided by Pilot One of Bedford. The company has sold a control and driver unit for the Lego Universal Buggy for some time now and it has incorporated the inexpensive mobile into its courses.

ROBOTICS REVIEW

Also included are the Pilot crane, model train system and car as well as the necessary interfaces, connectors, software, taking in 18 special routines, and literature. The result is a course which aims to teach the budding robotier the basics with as little outside assistance as possible.

The follow-up, surprisingly called Pilot in Control II, uses elements of the Fischertechnic robotics kit as an introduction to the mysteries of analogue feedback. The motors are connected to the micro using the digital interface and the potentiometers are connected using the internal analogue to digital converters.

The potentiometers and motors are combined in closed loop feedback systems created from Basic procedures which are part of the course.

Following that the course makes use of the Alfred kit from Robot City Technology, beginning with controlling the servos from the Alfred board and eventually making the complete robot arm to learn about its working and capabilities.

As a supplement Pilot has developed some Basic routines for use with Remcon's Teach Robot, the five-axis articulated arm powered by d.c. servos driving piston actuators. Alternatively the arm can be operated using the routines in Basil, Pilots control language for its digital interface.

The company has launched a further accessory for Teach Robot to help in the understanding of how arms work. It is a set of overlays for a keyboard which with the necessary software allows the arm to be controlled directly or to be given a complete routine which has previously been worked out on the keyboard and then stored.

Photo 2. *Omnibot Jr.*

At the time of going to press negotiations were being held to sell the stocks and manufacturing rights for the products of Colne Robotics, the Middlesex company which went into liquidation in February. The potential buyer was not named but it was hoped that agreement could be reached quickly.

Colne produced the Armdroid arm, Colvis vision system and various items of applications software.

READERS' LETTERS

Dear Editor

With reference to the letter from Mr. Reed on bulk erasure of tapes (*PE*, April 86), for some years I have been using a home-made gadget for this job.

This consists of a modified frame output transformer from an old valve television. As they are designed to run with a fair amount of d.c. in the primary winding the laminations are not interleaved, so it is usually quite easy to remove the clamp and the 'I' laminations, leaving the 'E' laminations and the windings intact. I just connected a mains lead to the primary winding and I have a bulk eraser.

To use, lay down on the back of the 'E' laminations, switch on and slide the cassette around on top for 2 or 3 seconds, pull away and switch off. You then have a blank tape.

I don't know if it would stand being powered for long periods as the winding may overheat. Perhaps some of the wizards at *PE* can work it out. I don't know enough about transformer theory.

I hope this is helpful.
Philip Honour, Marsh Gibbon.

Dear Editor

In reply to Mr. Reed's letter about his bulk tape eraser problem (April 1986), Tandy Corporation, who have shops all over England, do a tape eraser, catalogue number 44-7000, at a cost of £19.95, ready to use.

Whilst on the subject of help, I wondered if any of your readers had a circuit diagram of the Texas Speak and Spell toy, or pin-out diagrams of the i.c.s used. The i.c.s are: CD2303, CD2304 and the NA7949. I have tried to find details of these devices but have had no luck so far.

I would be glad to pay the cost of sending me such information. Keep up the good work, *PE*.
J. Murphy, Surrey.

Thanks to Philip Honour and J. Murphy—two solutions that we were not aware of. It just goes to show, if you have a problem there is always a solution.

If any one has further information or suggestions about the t.v. transformers or the Speak and Spell i.c.s, drop us a line and we will pass it on. Thanks, readers.
Editorial.

All letters regarding projects and editorial matters should be sent to "Readers' Letters", Practical Electronics, 16 Garway Road, London W2 4NH.

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Synth & 8-Bit I/O Port		
(double-sided)	023	£6.49
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Enterprise 64K–Z80A sound 256 colours, built-in joystick and various parts, £110. E. Forrester, 14 Gardner Close, Wanstead, London E11 2HN. Tel: 01-989 7294.

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Oscilloscope: Hameg HM 307 10MHz single beam, with component tester, manual diagrams, as new, no reasonable offer refused. D. Smith, 16 Dovedale Close, Owlsmoor, Camberley, Surrey. Tel: Crowthorne 778328.

2114 static rams, marked, most work, 34 for £35, will split. Also 4 8212s, each £1. R. Taylor, 29 Dunstall Road, Halesowen, W. Mids B63 1BB.

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AVO8s with leads £60, digital multi-

meter £60, lots of spares, ring for details. A. C. Freeman, 64 Oulton Crescent, Barking, Essex IG11 9HF. Tel: 01-594 4126.

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COMMENT . . .

A leading educationalist, Dr John Rae, headmaster of Westminster School, recently created a furore with the following statement: "I think we have one of, or possibly the worst, publicly maintained education systems of any developed country in the world." How right he is. It is a dismal fact that today a young person in Britain is less likely to receive an education beyond the barest minimum, than his or her counterpart in our main industrial competitors.

That the educational system should be so lacking when we as a nation are rightly proud of the number of Nobel Prize winners we produce, or of the often outstanding work done by our scientists in dismal laboratories on shoestring budgets is a difficult question. The answer is that although some of the finest academic work in the world is being done in British universities they comprise only a very small part of the educational system. Only 7% of British children will go to university. Compare this with 44% in the USA, 30% in France and 39% in Japan. A lower percentage of British children go to university than do children in any other industrialised country. A dismal fact indeed given Britain's attempt to keep its place in the world as a technologically advanced country. Especially when one also considers that only 44% of those who go to university take a science degree, compared to 68% of Japanese students.

YOUNG

The woefully inadequate number of technologically trained people produced by the British educational system seems to start at quite a young age. Only 18% of children in Britain will stay on at school after 16. With Britain's competitors the tale is different—34% of French pupils, 86% of American and a staggering 94% of Japanese will stay on after the official school leaving age of 16. The apprenticeship system in the past gave many the required education to allow them to work in an industrial society. But apprenticeship has now almost totally declined. In its place 32% of British children will do some further education, but compare this to Germany where 76% do so.

As the world becomes more complex the need for technologically orientated higher education becomes more and more necessary. It is terrible that Britain is the only country in Western Europe which allows pupils to drop maths as a subject at the age of 14. In every other country it is compulsory. British children are encouraged to specialise at an early age. Science subjects are hard, and in the pursuit of qualifications the soft arts subjects are taken in their place. By the time British children reach A level they will probably be taking no more than three subjects. In France seven subjects are required for a baccalaureate.

BLAME

Who is to blame for this woeful state? Education has for years suffered from political interference, but has consistently failed to live up to the ideological aims of its political mentors. The truth is that there is little that politicians can do. Teachers complain the pupil-teacher ratio is too high, 17 pupils per teacher on average in the UK, compared to 16 in the USA, 17 in France and 22 in Japan. They also complain about lack of funds yet Britain spends 5·2% of Gross National Product on education compared to 5% in France and 6% in Japan. None of the teachers' complaints withstand close scrutiny.

Perhaps we should blame the teachers. No, they are not at fault, most are hard working and dedicated. At fault is the national attitude towards education, which is usually one of indifference, but in science and technology, frequently of hostility. This national attitude is reflected in the pupils, in their lack of interest in science subjects and a general lack of enthusiasm for education. Go to a developing nation and look how children enthuse over their chance to go to school. The comparison can be depressing. In Britain the number of young people interested in electronics and technology is dwindling rapidly with probably less than half the number that there were ten years ago.

This sad situation will never change until there is a fundamental alteration in the national attitude towards education, particularly education in the sciences and technology. Such a change of attitude by the man in the street will only come about following a similar change by those who influence society. Too often we find that the popular media and the political world are full of people who know their Homer and can freely quote from Byron or Balzac but when questioned about science profess a smug ignorance. When was the last time a prospective so-called 'Brain of Britain' chose a science subject on Mastermind? No-one can remember, and the journalists are still talking about 'silicone chips'.

NICK HAMPSHIRE . . .

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