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We have recently received the following literature:

CPVE - A Link Between School and Work is the title of a leaflet issued by the Joint Board for Pre-Vocational Education. The leaflet is a simple guide and introduction to CPVE and will be of interest to students, parents and employers. Copies of the leaflet and other publicity material are available on request from The Sales Section, City and Guilds of London Institute, 76 Portland Place, London, WIN 4AA. 01-380 3050.

Maplin's 1989 catalogue is bigger and better than ever, and they've printed over 200,000 copies! It contains over 500 new products and has hundreds of price reductions in its 550 pages. As an introduction to the new range of Maplin cassette tapes, every buyer of the catalogue can send for two free C60 ferric tapes or one C60 chrome tape. The catalogue costs £1.95 and is available from any Maplin store, or from W.H. Smith. Maplin have also introduced a new professional supplies trade catalogue. Maplin Electronics, PO Box 3, Rayleigh, Essex, SS6 8LR. Tel: 0702 554161.

Eccentric are a company who will be of great interest to any electronics constructor who needs to interface mechanical assemblies to electronic control circuits - they stock Meccano parts! For some years your Ed has mourned the apparent demise of Meccano, but has learned that it's alive and well, and being comprehensively imported by Eccentric (who stock secondhand parts as well). I am sure they will be delighted to send you their catalogue and price list. Eccentric, Park Lane (off Park Street), Madeley, Telford, Shrops, TF7 5HE. Tel: 0952 583345.

Cirkit is a company consisting of three major divisions - consumer, educational and industrial, each division having its own team of experienced staff offering sales and customer service. Their new catalogue, priced at £1.30, will therefore be of considerable interest to any constructor in need of a broad range of electronic components, from the conventional to the less-easy to find. The catalogue also contains valuable discount vouchers, and information on an interesting competition with several prizes. Circuit Distribution Ltd, Park Lane, Broxbourne, Herts, EN10 7NQ. 0992 441306.

L.J. Technical Systems have a short-form catalogue covering many training systems, applications and courses. Though many of the services are aimed at professionals, dedicated amateur enthusiasts could also benefit from finding out more about this company L.J. Technical Systems Ltd, Francis Way, Bowthorpe Industrial Estate, Norwich, NR5 9JA. 0603 748001.

Integrated Measurement Systems brochure will be of interest to PC users. It covers a good variety of hardware and software that enables a PC to be linked to the outside world for numerous test, measurement and control applications in lab, industrial and engineering environments. Integrated Measurement Systems Ltd, 306 Solent Business Centre, Millbrook Road West, Southampton, Hants, SO1 0HW. 0703 771143.

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We have recently received the following literature:

Synthesiser Kits
For some time now there has been a noticeable shortage of synthesiser DIY kits on the market. Perhaps mistakenly you Ed had concluded that the sophistication of low cost ready made synthesisers had deterred kit suppliers from competing in this field.

Digisound have now announced their determination to put paid to this theory by introducing a new range of modular synthesiser kits. Tim Higham of Digisound informs me that their synthesisers are already used by a number of bands, including Wavestar who have just used on their latest album "Moonstar".

Many other music-orientated kits are available from Digisound and their range will be further increased in the near future by the addition of more keyboard and sound sampler kits. Drop Tim Higham a line and ask for a free copy of the glossy catalogue - he's at: Digisound, 16 Lauriston Road, Wimbledon, London, SW19 4TQ. Tel: 01-946 0467.

Kit form audio
Dramatic cost savings are possible by buying TIME MACHINE'S new range of fully professional audio processors in easy-to-build kit form.

Housed in standard 19 inch cases 1U high by 6 inches deep these units have tasteful modem styling and logical control layout. The General format is that of two independent channels which can be linked for stereo operation by means of a switch.

The range includes: the Activator (a sophisticated enhancer), a dual noise gate/fade/panner, a compressor/expander with adaptive radio, and the silencer single ended noise reduction system.

Kits retail for around £130 +VAT. Fully built and tested units are also available, with user manuals, at £199 +VAT. These prices include UK carriage.

CONTACT: TIME MACHINE, Abbotsford, Deer Park Avenue, Teignmouth, Devon, TQ14 9LJ. Tel: 06267 2353.
Gang of Eight
Dataman is relaunching its production erom programmer, the Gang-of-Eight. The latest version comes as standard in a robust steel case with bi-directional RS232 serial interface facilitating programming via PC. G8 will handle 2516, 2532 and 2564 eroms, as well as all 27 series from 2716 to 27512. Setting is by use of di switches. All settings are marked on the metal case for device type, programming speed and voltage selection. When programming, G8 checks that the slave devices have been erased and upon completion checks the match with the master. The led display confirms the stage of programming but to avoid visual monitoring G8 also provides audible feedback.

CONTACT: Dataman, Lombard House, Comwall Road, Dorchester, Dorset, DT1 1RX. Tel: 0305 68066.

Radical Rigging
Concerned amateur radio users can now purchase a radically new 2m fm transceiver. The AMR1000 is a quality British made rig and is a development of the RT6500vhf radio telephone, which after only one year has become the best selling vhf set in the marine market.

The rig is available in two forms. The AMR1000 is a simple to operate fully channelised set able to function on both 12.5kHz and 25kHz channel spacing. The AMR1000S has all the features of the AMR1000 but has additional features including full scanning and programming functions. Both sets feature a well laid out control panel with clear display.

A full range of power supplies, antennas and mounting accessories that allow the transceiver to be used at home or as a mobile are available. Prices start at around £247 for the AMR1000 and £299 for the AMR 1000S.

CONTACT: Navico Ltd, Star Lane, Margate, Kent, CT9 4NP. Tel: 0843 290290.

Scots Technology Show
SATRO North Scotland and SATLINC (Science and Technology Links in the Community) are holding their third Computer and Technology show at the Music Hall on Sunday 11th December from 11am to 5pm.

SATLINC is an organisation for the mutual support of technology clubs, and all profits from the show go to help the clubs. At the show are displays of the uses of computers and technology in education, commercial, stand display books, computers and software. Above all the many amateur clubs show some of the exciting things that can be done with electronics, computers and technology in general. There will also be a preview of SATROSSHERE, the permanent Interactive Science and Technology Exhibition due to open shortly in Aberdeen.

In short, there are entertainments for the whole family including competitions and games for the children.

Northern readers who want to know about local science and technology clubs will find that Steve Delaney, 50 Stewart Crescent, Northfield Avenue, Aberdeen. AB2 5SR, probably has interesting information to offer.

For further information on SATRO, contact Dr. Lesley Glasser, University of Aberdeen, Marischal College, Broad Street, Aberdeen, AB9 1AS. Tel: 0224 273161.

**COUNTDOWN**

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

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

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

Dec 20. IEEIE Computers for Engineers, Lecture SSEB, 75 Waterloo Street, Glasgow. 01-836 3357.


Feb 7-9. Smartex – the surface mounting technology exhibition. Wembley Exhibition Hall. 01-302 8585.

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


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Definitely a book to have prominently on a bookshelf.

I was gratified to see that a lot of unexpected terms were included.

It's good to find another book that used by the brain.

Definitely a book to put on your list of wanted Christmas presents.

What a delight this book will be to any dedicated lover of anything to do with dry, ingenuity, and devotion to the completion of a job once started. It is the complete pictorial history of how Alfred Forbes built a dynamo to power his house in New Zealand. In 1969 he had decided to Live the Simple Life, buying a plot of land miles from anywhere, building his own house, and then finding the Electric Power People practically needed an arm and leg to bring power in. Alfred decided to build his own power plant, assuming there would be a book on the subject. There wasn't.

Inder The Illustrated Dictionary of Electronics - Fourth Edition. R.P. Turner and S. Gibilisco. Tab Books. £18.75. ISBN 0-8306-2909-9. Tab Books have excelled themselves with this book. It has well over 600 pages containing more than 27000 terms used in electronics and more illustrations than I would care to count. There are ample cross-references and numerous data tables have been included. Although random checks reveal that not all terms known to me have been covered, it is, nonetheless, the most comprehensive electronics dictionary. I have come across and will prove invaluable to anyone interested in electronics.

Electronic Circuit Design - Art and Practice. T.H. O'Dell Cambridge University Press. £9.55. ISBN 0-521-35858-2. The author says that this book has grown out of the experience he gained while involved in lab courses in electronic circuit design for final year undergraduates. In writing the book, though, he has taken a wider view by aiming it at any reader who has access to a simple electronics laboratory. He recognises that theoretical knowledge is essential, but that electronic circuit design can only be learnt by doing. An understanding of mathematics is preferable for a full appreciation of this informative book.

Experiments in Artificial Neural Networks. Ed Reitman. Tab Books. £13.20. ISBN 0-8306-1337-8. Altogether, I find hi-tech is still not high enough to improve my memory by means of a chip or two. Still, I'm interested by this book which describes simple neural working systems that can store and retrieve information in a fashion similar to that used by the brain. It is basically an introduction to computer modelling and hardware experiments in this fascinating field of artificial intelligence. There are three projects, and a good variety of illustrative programs. The latter have been written for IBM clones, using MS-DOS and GW BASIC. It looks as though there is food for thought in this book.

Benchmark Book Company, 59 Waylands, Swansley, Kent, BR8 8TN. Tel: 0322 64042.

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

Heinemann Professional Publishing, 22 Bedford Square, London, WC1B 3HH. Tel: 01-637 3311.

PC Publishing, 22 Clifton Road, London, N3 2AR.

Tab Books are imported from the USA by John Wiley and Sons Ltd, Baffins Lane, Chichester, W. Sussex, PO19 1UD. 0243 779777.

Todd-Forbes Publishing, PO Box 3919, Auckland, New Zealand.

CORDLESS PHONES

BY BARRY FOX
Winner of the UK Technology Press Award

CORDLESS PHONES

Just when you thought the penny had dropped about 'standards', four different manufacturers are still looking for ways to reconcile their products.

CORDLESS PHONES

Cordless telephones, as currently on sale for £100 or less, come in two parts: a mains-powered base station which plugs into the owner's home telephone line and a battery-operated handset which communicates with the base stations by two-way radio link. Transmitter power is limited to 10mW, which reduces communication distance to 50 metres in a building or at best 1 kilometre outside. The radio link carries speech as an analogue signal, which makes it prone to interferences and insecure. Passing cars with cellphones can eavesdrop the cordless link line. Anyone with a matching receiver can eavesdrop on someone else's conversation and sometimes even make calls on their base station and thus at their expense.

The second generation cordless telephone, or CT2, is an all-digital system, with speech transmitted as code. This gives better sound quality and much greater security. The dti has allocated a 4MHz slice of the uhf radio spectrum between 864MHz and 868MHz. This can accommodate 40 channels, each 100kHz wide.

Unlike conventional cordless phones, which use two separate radio channels for each half of a conversation, CT2 makes do with a single channel. The digits representing each half of the conversation are chopped up into small packets which alternate pass down the radio channel in opposite directions and are reconstructed at each end of the link for apparently continuous analogue speech. This technique, called "ping-pong", allows the 40 channels to carry 40 conversations.

Because the speech is digitally coded, the data stream can carry hidden extra codes which identify each user. This will make it possible for owners of CT2 handsets to use them not just at home with their own base stations, but with public base stations provided by entrepreneurs in busy streets, shops, railway stations and airports. These base stations will connect calls from handsets to the BT or Mercury network and later bill users on their own home phone accounts.

In the spirit of free competition the dti set a flexible standard operating standard (MPT 1354) in April 1987. This specifies only the frequencies to be used and leaves individual manufacturers free to devise their own solutions to the tricky problem of squeezing two ping pong channels of speech into one 100 kHz radio channel.

At least four rival consortia have risen to the challenge and developed different coding systems, which are all incompatible with each other.

Shaye Communications at Winchester, grew out of a laboratory set up by Sir Clive Sinclair. In August last year Nokia Mobira of Finland paid £2.5 million for a 25% share of Shaye. The rest is owned by Fred Olsen, his Timex group and Sinclair Research. Shaye owns patents dating back to 1985 on CT2 technology which cleverly conserves battery power by setting transmission strength of the handset to the rock bottom limit needed for successful communication. Shaye plans to start selling mass-produced handsets before the end of the year. Bill Jeffrey of Shaye describes CT2 as "a tremendous opportunity, equivalent to home computers or video".

Rival company Libera, now owned by Ferranti, has been working on CT2 since 1986 and also plans to start selling systems this year. Libera has already built working prototypes of both handsets and public base stations. Libera has for two years been pressing the dti for an air interface standard which defines the signal coding, so that any handset will match any base station. The company has had enquiries from abroad, but European countries, like France and West Germany, with monopoly control of the telephone system, will not buy any technology unless it conforms to an approved European standard.

BT came late into CT2, placing a £5M contract with STC in July 1987, to develop a third system. GEC and Plessey are working on a fourth system, believed to be for use with Mercury. They are especially interested because the same technology can be used to provide buildings with cordless telephone switchboards.

British Telecom plans to install 5000 public base stations of phonepoints round the country but is waiting for the government to approve its involvement. Reluctantly BT acknowledges that it will have to install two, three or even four different base station systems at each location if all handset systems are offered for sale.

Recognising the absurdity of the current situation, which kills everyone's chance of selling their technology abroad, the rival manufacturers are now trying desperately to hammer out a solution that does not kill them all. Three months ago the DTI set a deadline of July for agreement. It passed.

Paul Hermer, commercial director for the Libera project at Ferranti notes ruefully: "Things are best for those who have done the least development work. For them it will be relatively cheap to change. Those who have taken the biggest risks, and done the most development, will have to foot the biggest bill for making changes".

Changing technical specification will most seriously affect Ferranti - Libera and Shaye, because they have already designed microchips for mass production. GEC, Plessey, BT and STC are still at an earlier stage of development. Shaye and Ferranti will look for compensation if they sacrifice their lead to help the rival companies compete for what BT describes as "the glittering prize" of sales to Europe.

Continued on page 17
There is a feeling of time-warp around the office as we go to press with this issue.

The cover date is January 1989, yet, as is customary, it is published around three weeks before Christmas. This gives you masses of time to build some of the projects – the Christmas Flashers should make a good place to start. Or how about emulating Sherlock Holmes in a little bit of shadow play? The original idea may be nearly a century old, but villains still abound.

We are just as conscious of another time-warp factor, and it’s of special significance to PE. You’ve probably noticed the ‘25 Years’ motif we proudly display on this page and on the front cover. It’s not just part of the cartoon – it’s there because it means it – ‘89 is the twenty-fifth year since PE was first published.

Around 25 years ago a certain Fred Bennett and his colleagues were busy plotting to revolutionise the hobbyist electronics world. They had in mind a magazine that would show how electronics could interest a much wider readership than existed for the prevailing periodicals. These had titles mostly containing the words ‘wireless’ or ‘radio’ – words which largely described their contents. Fred and Co believed that a magazine with a broader electronics outlook would encourage more people to participate in a technology that could do far more than handle radio signals.

With Fred as it’s founding editor, PE was destined to take the bookstalls by storm, starting with the November 1964 issue. Since then the electronics world has witnessed many changes and PE has played a vital role in keeping an international readership well informed about them.

PE continues to play the same role, and with the sophistication of modern technology there is enormous scope for people of all ages to become part of the hi-tech scene, and to learn how to understand it.

In making plans to celebrate our Silver Jubilee with the November 1989 issue, we are constantly reminded of the part PE has played for a quarter of a century. We are confident that we shall guide you into the even-more revolutionary electronics world of the twenty-first century.

Before then, though, we shall indulge in a little nostalgia by looking back at some of the key events of our first 25 years. Many of you, like myself, have been reading PE since Issue One, others have more recently discovered PE and the addictive nature of electronics. How about joining in with the nostalgia? No doubt you have reminiscences related to PE and the project or feature articles presented over the years. If you have, drop me a line or two, and the most interesting tales will find themselves on the Letter’s page. I shall also be pleased to know of any early PE projects you still have.

In the meantime, and to celebrate a more immediate festivity, we all wish you Season’s Greetings, and the best of luck in our LCD TV Competition.
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The germ of the idea for this project comes from Sir Arthur Conan Doyle's story. The adventures of the Empty House. The house in question was Camden House situated in Baker Street, London, exactly opposite to Sherlock Holmes' room at No. 221B. Holmes and Dr. Watson had entered the empty house at night and were in a room facing on to the street. Watson takes up the story:

"I crept forward and looked across at the familiar window. As my eye fell upon it, I gave a gasp and a cry of amazement. The blind was down and a strong light was burning in the room. The shadow of a man who was seated within was thrown in hard, black outline upon the luminous screen of the window. There was no mistaking the poise of the head, the squareness of the shoulders, the sharpness of the features. It was a perfect reproduction of Holmes. So amazed was I that I threw out my hand to make sure that the man himself was standing behind me. He was quivering with silent laughter."

Holmes then explained that the shadow is cast by a specially-made wax bust of himself. It is intended as a decoy to lure Colonel Moran - Holmes' arch-enemy since the death of the infamous Professor Moriarty - into a carefully laid trap.

Later, Watson continues:

"I was about to make some remark to him, when I raised my eye to the lighted window, and again experienced almost as great a surprise as before. I clutched Holmes' arm, and pointed upward. "The shadow has moved!" I cried. "It was indeed no longer the profile, but the back, which was turned towards us."

"Three years had certainly not smoothed the asperities of his temper or his impatience with a less active intelligence than his own."

"Of course it has moved," said he. "Am I such a farcial bungler, Watson, that I should erect an obvious dummy, and expect that some of the sharpest men in Europe would be deceived by it? We have been in this room two hours, and Mrs Hudson (Home's housekeeper) has made some change in that figure eight times, or once in every quarter of an hour."

The lure worked. Colonel Moran too entered the empty house, with the intention of killing Holmes as he sat by his window, using an ingeniously made and extremely powerful air rifle. Holmes and Watson surprised and overpowered the Colonel who was later arrested and brought to trial on several charges.

PROJECTION
This project is designed to throw moving shadows on the curtains of a room at night. Its aim is to give an observer the impression that the room is occupied. An intending intruder, believing that there is someone at home, will decide to try elsewhere.

In recent years there have been many devices marketed to turn room lighting on and off during the hours of darkness. One of the problems with these is that any type of regular switching is bound to be recognised as such by the intending intruder. It fails to act as a deterrent. Some of these devices can be programmed to switch the lights on and off frequently during the evening, with fairly irregular timings. The idea is that the frequent switching on and off of the lights is a sign that someone is there, doing the switching. Yet, in the typical household, the living room lights go on at dusk and stay on until bedtime. The effect is far from realistic. Holmes was right (as always!). There must be signs of activity within. Moving shadows are required. Holmes did not have the benefit of modern technology to help him, but his housekeeper did the job reasonably well.

SHADOW SHOW
This project goes several stages beyond the Holmes subterfuge. The shadows actually move and in an apparently random way. There are periods of active movement with intervals of no movement. All of the following are determined randomly:

* the length of the active periods
* the length of the intervals between movement
* the speed of movement
* the amount of movement
* the direction of movement, which may sometimes change during a movement

The shadows are cast by a suitable object or objects placed on a platform. The platform is rotated from time to time by a stepper motor. As the platform rotates, the shadows move across the curtains.
RANDOM NUMBERS

Although Holmes did not instruct his housekeeper to change the position of the bust at irregularly spaced times, it is likely that she would have done so in practice. Busy with her other duties, she would spare the time to move the bust at roughly but not precisely regular intervals. Too much precision would have given the game away to the intelligent observer. Electronic circuits are inherently regular in operation. We must find some way of introducing a little randomness. Then the observer will be fooled into believing that there is a real live randomness.

The system (Fig. 1) is based on a random number generator built from a shift register. Although the sequence can be predicted (you can do it easily on paper if you do not have access to a computer), the practical effect is the same as if you took a coin and threw it 32767 times. Throwing a coin would give a truly random result, with roughly equal numbers of head and tails. The sequence obtained with the shift register is not truly random because it repeats itself eventually. But it is near enough to random to suit our purpose. It is pseudo-random. Incidentally, shift-registers are used in a similar way to generate the 'white noise' in sound-effects ics.

USING RANDOMNESS

When the system is running, a pseudo-random sequence of binary digits is shifted along the register. We make use of the randomness to obtain the random movement of the shadows. There is little chance of an observer detecting any pattern in the activity. The sequence is so long that it takes several days of continuous running before it repeats.

To see how this is done, we return to Fig. 1, starting at the top left-hand corner. The two clocks are designated 'Fast' and 'Slow'. The fast clock determines how active the shadows are when they move. By setting the rate of this clock you can make it seem that the occupant of the room is a brisk, alert person, or rather more ponderous in their movements. The slow clock determines the average length of time between periods of movement. The apparent occupant can be made hyperactive or slothful.

The 'clock select' sub-circuit is used to determine which of the clocks is driving the circuit. A logic low on the 'clock select' line selects the fast clock during active periods. A high level selects the slow clock between active periods.

The selected clock pulses are fed to a counter, with four outputs running a half (A), a quarter (B), an eighth (C) and a sixteenth (D) of the selected clock rate. The slowest rate (D) is used to shift the register. Since the fast clock runs about four times quicker than the slow clock, the register is shifted about four times as quickly during active periods. The apparent occupant of the room is a brisk, alert person when the fast clock is used and a more ponderous creature when the slow clock is used.

The counter outputs go to a demultiplexer, the function of which is to select one of the counter outputs for stepping on the motor. Output A gives the fastest movement while output D gives the slowest. The rate selected depends on the state of the 'rate select' inputs. These inputs are taken from flip-flops 2 and 3 of the register, and not necessarily adjacent ones. The rates selected are A, B, C or D when the flip-flop contents are 00, 01, 10 or 11, respectively. As the sequence of digits is shifted along the register, an irregular sequence of 00s, 01s, 10s, and 11s appears on the output select lines, selecting speed of movement apparently at random.

The output from flip-flop 16 (again, we could have chosen any flip-flop to provide the digit) decides whether the motor is to rotate clockwise or anti-clockwise.

**Fig. 1. System Logic Diagram**

**Fig. 2. 25 Consecutive Stepping Stages**
We find it hard to suppress a note of triumph when writing about this part of the circuit. Years and years ago we read about the majority logic gate. It sounded much more interesting and impressive than the boring old NANDs and NORs. Here is democracy in electronic form! The majority vote wins. There are five inputs and, if three (any three) or more are high, then the output is high. Or, by using the W input, you can make it work the other way round. So we bought a 4530 ic, which contains two such gates. After experimenting with it and finding that it worked as specified, we consigned to our stock. In over a decade we have never found a use for it - until now!

In this circuit, its output goes low when any three of flip-flops 4 to 8 hold logic '1'. This triggers the beginning of an active phase. The output of the majority logic gate is used to select the fast clock and to enable the NOR gate. Pulses from the clock then pass through to the stepper motor control ic.

The design uses flip-flop 4 to 8 to control the majority logic gate, but any five flip-flops, not necessarily adjacent, could be used. With the present arrangement, which uses consecutive flip-flops, once flip-flops 4, 5 and 6 are high, there will be at least three high outputs for the next two shifts. If more '1's are shifted into these flip-flops the gate output will be high for even more shifts. This gives a good chance of the motion continuing during several shifts, perhaps at different speeds and possibly with changes in direction. The result is periods of varied activity with relatively large breaks in between. This is another way in which you can control the 'personality' of the Holmes Machine. It is mainly a matter of experimentation to obtain the effect that you think is right.

The 4530 ic contains two majority logic gates but, so far, we have found a use for only one of the gates. Now comes the ironic part. We need a NOR gate and it seems a waste to use a whole 4-gate ic to supply a single NOR gate. There is a majority logic gate to spare and, with a little ingenuity (Fig. 3), it can be used as a boring old NOR gate. So, if anyone else has an unemployed 4530 in their junk-box, here is a way of using it, at last!
clocked simultaneously by pulses from the
The 16-bit shift register is made from two
ply for selecting logic levels. The -5V pin
the 4052 (beware the similarity in the ic
which only one is used. Its outputs go to
+12V.

The 4520 ic has two 4-bit counters, of
minal (R) is not used, being connected to
1 -of -4 switch. This ic can also switch ana-
logue signals but here we are using it sim-
dual circuit. Wear clothing of natural fibres, not
sythetics. Touch an earthed metal surface
frequently while working and touch sharp-
pointed tools such as forceps, pliers and
crewdrivers against this surface every time
before the tool is used.

Fig.6. Board 3: Control logic

mode terminal (M) of the ic. The reset ter-
mental (R) is not used, being connected to
+. Board 3 (Fig. 6) holds the Holmes logic.
The 4520 ic has two 4-bit counters, of
which only one is used. Its outputs go to
the 4052 (beware the similarity in the ic
numbers) 4-line-to-1-line demultiplexer, or
1-of-4 switch. This ic can also switch ana-
logue signals but here we are using it sim-
ply for selecting logic levels. The -5V pin
(pin 7) is therefore connected to the 0V line.
The 16-bit shift register is made from two
4094 ics cascaded in series. They are
clocked simultaneously by pulses from the
D output of the counter. These are serial-in-
parallel-out registers with serial outputs.
The Q5 serial output (slow-speed serial out-
put) of the first register is used to feed the
data from flip-flop 8 to the first flip-flop of
the second register.

Connections from the flip-flop outputs to
the majority logic gate, the select input of
the demultiplexer and the direction control
are shown in Fig. 6 as they were in the pro-
totype. However, many other configura-
tions are possible, as explained above. The
only essential is the connections to the ex-
OR gate must come from Q6 and Q7 of
IC8, as shown.

The 4530 majority logic gate ic (IC10)
contains two identical gates. Each gate pro-
duces a logical high when any three or more
inputs are high. The output from each gate
goes to an exclusive-NOR gate on the chip.
The other input of this gate is via terminal
W. Thus, if W is held low as in this circuit,
the output from the majority gate is inver-
ed. Output low when three or more inputs
are high.

CONSTRUCTION
The main point to remember is to take
the usual anti-static precautions when han-
dling the ic os ics (IC3-IC10 inclusive).
Do not insert these ics into their sockets
until a sub-circuit is built ready for testing.
Remove them and place them on conduc-
tive foam while building the next sub-cir-
cuit. Wear clothing of natural fibres, not
sythetics. Touch an earthed metal surface
frequently while working and touch sharp-
pointed tools such as forceps, pliers and
crewdrivers against this surface every time
before the tool is used.

Build the power supply first. The proto-
type has its main switch incorporated in the
mains lead, but a toggle switch can be
mounted on the case if preferred. The
transformer is bolted into one corner of the
case. Board 1 (Fig. 7) holds the remainder
of the power supply components and is
mounted on two short bolts beside the
transformer. A heat sink is required on the
regulator ic. It is advisable to bore ventila-
tion holes in the case and lid. Take care
with exposed mains wiring when testing the
power supply circuit. As soon as it is work-
ing properly, run supply leads from Board 1
out through one of the holes in the case.
Then screw the lid firmly down to eliminate
risk from contacting the mains side of the
power supply circuit.

Next build and test the clocks (Fig. 8).
Timings are not critical. Indeed you may
decide to vary the clock speeds to obtain a
given effect. Increasing R2 from 820k to,
say, 1M or 1M2 gives a slower movement.

Fig.7. (Below). Fig.8. (Right)
Component layouts and track views
for boards 1 and 2 respectively
Reducing it to, say, 560k or 680k increases movement rate — but would the occupant really move around that fast? Similarly, the value of R4 determines the length of time intervals between periods of activity. Thus the greater the value of R4, the longer the times. The NOR gate IC (IC4) completes this section of Board 1. When ready, monitor the output (use an LED, a logic probe, a voltmeter or an oscilloscope) from IC4 pin 11 as the clock select input is connected to 0V or +12V. A low input selects the fast clock. It is convenient for later testing if the clock select input pin is wired temporarily to 0V at this stage. Leave the other section of this board until later.

On Board 3 (Fig. 9), begin with the counter IC (IC5) and check its outputs. Then add the demultiplexer (IC6). Monitor its Q output while connecting the A and B select inputs to 0V or +12V:

<table>
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<tr>
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<th>Output same as from</th>
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<td>B: A</td>
<td>IC5, output</td>
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<tr>
<td>0V</td>
<td>0V</td>
</tr>
<tr>
<td>12V</td>
<td>0V</td>
</tr>
<tr>
<td>12V</td>
<td>12V</td>
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Build the shift register next (IC7, IC8). Do not connect it to ICs 6, 9 or 10 yet. Connect the data input (IC7 pin 2) temporarily to 0V. Quickly the flip-flops all fill with '0's. Monitor pins 4-7 and 11-14 in both ICs to ascertain this. Then connect pin 2 temporarily to +12V. The flip-flops quickly fill with '1's. Now add the ex-OR gate (IC9) and complete the feedback connection to the register. You should always be able to find at least one flip-flop with a high output. It could happen by chance that all flip-flops assume the '0' state when the circuit is switched on, but this is unlikely and has never yet happened in the prototype. If you do get 'all zeros', switch off and then on again.

Connect the register to ICs 6 and 10 and wire up the rest of IC10. The three outputs from this sub-circuit may now be tested. The 'direction' output alternates irregularly between '0' and '1'. The 'clock select' output alternates similarly. The 'step on' output alternates continuously but at varying rates, depending on which rate is being selected by the demultiplexer.

Finally make up the stepper motor control circuit. This has its own supply leads form the power supply unit to reduce the risk of transients affecting the shift register.

Interconnect the boards for final testing. This is the point at which the 'clock select' line on Board 2 is connected to the 'clock select' pin on Board 3 instead of the 0V line. The leads of the stepper motor are usually colour-coded, and the coding should be set out on the leaflet accompanying the motor.

Switch on the power. From now on, you may have to wait for several minutes while the circuit is in its inactive phases. A paper pointer fixed with 'Blutack' to the spindle of the stepper motor helps to show what the motor is doing. When power is switched on, the motor should soon (or after several seconds) begin to rotate. It may rotate one step (7.5°) or several steps. It may rotate clockwise or anticlockwise. Then there is a pause during which nothing seems to be happening. Be patient! Sooner or later, perhaps after a minute or more, the motor resumes activity again.

If all seems to be in order, mount the motor on the lid of the case so that its spindle projects up through the lid. Place the boards in their slots and screw down the lid of the case.

**TURNTABLE**

There are various ways of making the turntable that carries the shadow-producing objects (Fig. 10). In the prototype, an old Meccano bush wheel was used for mounting. You could use a block of hard rubber (eg a bottle stopper such as that available from a home-brew store), with a hole drilled to be a tight fit on the spindle. The platform can be glued to that. That platform, which can be square, rectangular or circular (or completely irregular in shape) is made of any available material — plywood, hardboard, or metal. We used a spare piece of Formica laminate.
PRACTICAL ELECTRONICS JANUARY 1989

R6220, I W

RESISTORS
R1,R3 10k (2 off)
R2, R2 820k (but see text)
R4 27k (but see text)
R5 100
R6 220, 1W
All 0.25W carbon or 0.6W metal film, 5% unless otherwise specified

CAPACITORS
C1 200µ (electronic 16V or 25V
C2, C3 100µ (polyester (2 off)
C4, C7 10µ (polyester (2 off)
C5, C9 100µ (electrolytic 16V or 25V (2 off)
C6 1µ (electrolytic 16V or 25V

SEMICONDUCTORS
D1-D4 1N4005 rectifier diodes, 1A (4 off)

INTEGRATED CIRCUITS
IC1 7812 12V regulator
IC2-IC3 555 timer (2 off)
IC4 4051 quad 2-input NOR gates
IC5 4520 dual 4-bit binary counter
IC6 4052 dual 1-of-4 analogue switch
IC7, IC8 4094 8-bit shift register (2 off)
IC9 4070 quadruple exclusive-OR gate
IC10 4530 dual major logic gates
IC11 SAA1027 stepper motor driver

Miscellaneous
T1 transformer 15V, 12VA
M1 stepper motor, 12V, bi-directional, 4-phase, 7.5° step angle
S1 SPST mains switch
8 pin dils (2 off), 14-pin dils sockets (2 off), 16-pin dils sockets (6 off).
Stripboard 10 strips by 10 holes (eg Vero 10347, 36 strips by 50 holes, 127mm x 95mm) – may be more or less than 41 holes if case dimensions different.
1mm terminal pins (24 off), abs box 190mm x 110mm x 60mm, nuts and bolts for mounting boards, fixing feet, grommet, plastic feet (4 off), materials for turntable and shadow-casters.

PLATFORM
There is one point to consider when deciding which material to use for the platform. The action of a stepper motor is somewhat ‘springy’. In moderation, this produces a natural non-mechanical action. In excess, it can produce a rather unnatural effect – the would-be intruder might think that you have a roomful of kangaroos. This effect can easily be damped down by making the platform sufficiently massive. Make it of thick wood or of metal sheeting. Alternatively, place a small object of mass about 1kg on it.

The most suitable diameter for the platform depends partly on the geometry of your room. A large platform will produce a greater movement of the shadows, allowing them to pass off the curtains and apparently out of the room.

The platform carries models or cut-outs to cast the shadows. It might be appropriate to have cut-outs showing a man playing the violin, holding up a test-tube, or smoking a pipe. However this is carrying the illusion too far. Avoid trying to emulate a Javanese shadow-puppet show and go for much more subtle designs. The outlines of the models or cutouts need not resemble humans closely. We found that a small pepper-grinder provided most acceptable shadows. The objects or cutouts can be fringed with semi-transparent paper or plastic sheet, to blur the outlines.

MODIFICATION
An interesting modification is to use a platform surfaced in rough-textured Formica. The objects slide about slightly as the platform rotates. The platform needs an edge about 1cm high to prevent them falling off. This adds even more randomness to the motion.

The source of light should be a small table-lamp, preferably with an adjustable mounting, an opaque shade and a reflector bulb. Place this so that the shadow or shadows are cast on the drawn curtains. If you have several models or cut-outs on the turntable, arrange it so that they do not all cast shadows on the window area at any one time. The shadows should be active but confusing to the observer. Therefore have the other room lighting on at the same time, so that the shadows are diluted and made more obscure. If you are out and the room lighting and the shadow-casting are switched off automatically at bed-time, the Holmes Machine’s busy evening is brought to a realistic conclusion.

Glossary
Shift Registers
A shift register is a series of flip-flops, each of which holds one bit of data (0 or 1). This circuit uses a 16-bit register, after its registers might hold the data:

\[
\begin{align*}
A & = 0 \\
B & = 0 \\
C & = 1 \\
D & = 1 \\
E & = 1 \\
F & = 0 \\
G & = 1 \\
H & = 0
\end{align*}
\]

The shift register receives pulses from a clock circuit. At each clock pulse, the data is shifted on from one flip-flop to the flip-flop next door. In the example, a single shift would give:

\[
\begin{align*}
X & = \text{1100101011100010}
\end{align*}
\]

The X indicates that the data shifted into the first flip-flop depends upon what was presented at the serial input of the register when the shift occurred. The data that was in the last flip-flop has been shifted out, and lost.

Exclusive-OR
This is the 'same or different' logical operation, performed on two inputs. The result is low if the inputs are the same, and high if they are different. It is the logical equivalent of 'One OR the other, but not both'. This is the truth table:

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Elementary
Had Holmes been living in our era, I am sure he would have added to the deception by also ensuring that the tv was tuned on, allowing its screen flicker to fall on the window blind as well.

Ed
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On a modern railway system, from the time that a passenger parks the car, buys a ticket, checks the train departure time and travels on the train, right through to arriving at the destination, it is more than likely that dozens of independent systems of electronic wizardry will have been used to assist the passenger's journey. It is probably just as likely that the same passenger is completely unaware of the extent of those systems, merely because they are not generally within the sight of the public eye.

However, with the volume of rail traffic on a modern railway today, whether it be freight or passenger traffic or both, it is evident that the electronic and computerised scene is here to stay, because without it the efficiency of the railway would be very, very poor.

This article is the first of a series of three which will look at the inroads that have been made into the railroads of today by modern electronics. During the course of the articles we shall identify those systems used in railway signalling and they look at electronics in the rest of the railway scene.

RAILWAY SIGNALLING

Railway signalling has come a long way in the 160 years or more since the first passenger carrying train in the world was permitted to run, in the United Kingdom.

The first attempt to control the safe passage of trains was made with the use of "railway policemen" who displayed flags (red for "stop" and green for "all clear") to the drivers of trains in order to permit access through the advance track section and on to the next policeman. (In Britain these policemen, who were the forerunners of today's signalmen, gained the nickname "Bobbies" after the then Commissioner of the London Metropolitan Police, Sir Robert Peel. This name has stuck and, even today, Britain's signalmen, even those in modern sophisticated signalling control centres, are still nicknamed "Bobbies".)

Since those early days signalling has progressed quite a lot, from the introduction of mechanical semaphore signalling through to colour light signalling and now to "cab signalling" or even to completely automatic driverless trains which are controlled by electronic signalling. At the same time, it is ironic to note that in some places the most modern systems in use can be found only a few miles away from the signalling of yesteryear.

VITALITY

Signalling systems fall into two categories. "Vital" systems, by definition, are used to control the safety side of the signalling system. "Non-vital", or "Less-vital", systems are those systems which, under failure conditions, will not affect the safe running of railway traffic in any way, even though the failure in itself may probably cause some disruption to services.

It is in this latter category, that of the "non-vital" systems, where the first use of electronics was to be found. One of the first devices to be developed for signalling use was the Train Describer, or "TD", not a signalling device in itself but, rather, an aid to the signalman. Used as an intended replacement of the old system of train recording whereby signalmen would record the train's number as the train passed a certain fixed point on the track, say a starting signal. It was also used as a replacement...
for the “bell code” system in which a signalman would “describe” a train’s type to a signalbox in advance, eg, fully braked freight or express passenger. The train descriptor allows a signalman to identify by train number the position and type of a particular train which is either within his control area or approaching it. Used in conjunction with track circuit indications on his control panel or, on an ultra-modern installation, his visual display unit, the train descriptor automatically progresses through a signalling section or on to the next signalling control centre.

REMOTE CONTROL

Another early use for the computer in the signalling field was in the introduction of the remote control system. Where a signalling control centre controls a signalling interlock several miles away, there has to be some way of operating the relays which in turn control the signals and points at the interlocking. In the past the practice was to provide direct wire connections using multicore signalling cables. With the ever-increasing costs of copper cabling, though new methods had to be found to perform the required task. Hence the development of the time division multiplex (tdm) remote control system. TDM involves the sequential scanning by a computer of a number of relay contacts (representing the signalling output functions) at the control centre. The information thus obtained is then sequentially transmitted over just one pair of wires to a second computer at a remote, or “field”, interlocking and here the information is decoded to operate the required functions. There is, therefore, a vast saving in copper wiring between the control centre (or “office”, as it is known) and the remote location. Hence there is a saving in overall costs, even though a transmitter/receiver computer system has been used. Because the system is used as an aid to the control of vital signalling equipment, rather than controlling them directly, it is said to be “non-vital”.

With the tdm system, a period of time is divided up by a number of functions being transmitted sequentially from one end of the system to the other. There is another system in use whereby a number of functions are transmitted/received over two wires, at unique frequencies for each function. With this system, known as fom, or frequency division multiplex, either “vital” or “non-vital” information can be distributed, depending upon the design of the system used. This system is invaluable where information may not necessarily need to be transmitted all the way along the total control system. For example, a road/rail level crossing may need to be controlled somewhere between the “office” and “field” locations.

INTERLOCKING

What of the interlockings themselves? Indeed, what is an interlocking? This is the location where the logical checking is carried out to ensure that no signal route becomes free to be operated until all opposing signal routes are first normalised and until all points are set in their correct positions for the safe passage of trains. Also, any other equipment or functions, such as groundframes, level crossings, etc, must be correctly set/normalised as required.

In the past the interlocking was carried out mechanically using rods, locks and tappets within a signalbox lever-frame. Lately, the mechanical mechanisms have been replaced by relay interlockings whereby electrical circuits have provided the (vital) checking as required. However, now we have witnessed the first of the computerised interlockings. Called “solid state interlockings”, or ssi, there may be two or three computers which, through their pre-determined programs, check their own and their partners’ operation. This ensures and maintains the integrity of
the safety which would previously have been allowed with the relay interlockings. At a fraction of the cost of a relay interlocking, the ssi is the latest innovation to hit the signalling industry, with savings in times of installation as well as the cost involved in carrying out such installations. In addition, the buildings used to contain the equipment are much smaller than the conventional "relay rooms" of the past.

TRAIN DETECTION
Mention was made earlier of the "track circuit". This forms the very basis for any signalling system and is the means of detecting the presence of a train on a railway line. In essence, the track circuit is an insulated pair of rails which have a power supply at one end of the rails and a detection device, say a relay, at the other end of the rails. Without a train present on the track the detector is in the "track clear of trains" state. If, the detector is a relay, this will be in its energised state, where the power supply is feeding the relay’s energisation coil.

Once a train enters the area of the track circuit the power supply is effectively removed from the circuit and the detector goes to the "train present" state. Again, if the relay is being used, this will de-energise. Thus an effective means of train detection is available. In the past, and even now, the track circuit

EXTREME TEMPERATURES
In some colder countries the railways have many problems due to the freezing up of point switches. This can involve delays to traffic while rail staff work to unfreeze them by applying either heat or de-freezing chemicals.

A better answer is to use automatic point heaters. In this method electronic sensors detect when the ambient temperature drops to a critical level. Automatic circuits are then operated which ignite a propane gas jet aimed at the point switches, thus melting the ice or snow.

At the opposite end of the temperature scale, heat can cause quite a lot of problems also. If a train’s axle box overheats, say through the leaking out of lubricants, rolling stock can catch fire, sometimes with disastrous results. Some railways use “hot axle box detectors” which are electronic devices installed near the rails. These detect when an axle box of a vehicle is significantly higher in temperature than other axle boxes within the same train, working on the principle that not all the axle boxes will be running hot at any one time. The detector then transmits a message to a control centre or signalbox and records the details of the train concerned and even the exact vehicle and axle involved, so allowing the train to be stopped and inspected.
Fig.4 Automatic point switch heaters

WAGON SORTING

Staying on the subject of detection devices, consider the freight yard. In some countries "hump yards" are used in which a shunting train has its "consist" of wagons uncoupled in such a way as will allow their correct separation into the required sidings. The information of the wagons "cuts" or locations is entered manually into a computer, along with details of their required destination sidings. A shunting locomotive then propels the entire train up and over a hump in the track at a constant low speed. As each cut of wagons goes over the hump, gravity allows them to run down the slope towards the receiving sidings. Special air-operated retarders slow down the rolling wagons if necessary. Point switches are operated to the correct positions for the route to the desired sidings for that cut of wagons.

There are several detectors involved in the process. Each wagon, or cut of wagons, is dynamically weighed while rolling down the slope and acceleration is detected. This enables the correct "rollability" factor to be computed, and hence the correct air pressure on the retarders. As a parallel example, an egg can be held by very little pressure. However, apply too much pressure and the egg is crushed. Likewise, if too much pressure is applied to retard a wagon, then the wagon can literally be squeezed off the track. The whole process is computer-controlled to make the procedure as efficient as possible.

To be concluded next month

The photographs in the Electronic Railway article have been kindly supplied by GEC-General Signalling Ltd.

X-TRA BYTE SIZED

Integrated circuit manufacture currently depends on the use of visible light and optical techniques to literally print the circuit on the chip. With the call for smaller and faster chips, optical techniques are becoming increasingly incapable of the fine resolution required to minimise component size. Researchers are currently turning to investigating X-rays as the possible successor to light rays for the next generation of devices. Having a very short wavelength, X-rays can create extremely sharp edges when projected through the printing masks. The penetrating power of X-rays presents problems, though, and the researchers, notably at IBM, are having to create special mask materials. There is the additional problem of focussing the X-rays, which unlike light, cannot be diverted by lenses. Controlling the masks have to be cut to the precise sub-miniature size by an electron beam. Using an electron accelerator storage ring to boost the X-ray power available, IBM has demonstrated that line definitions can be obtained that could enable 64 million megabyte chips to be reliably manufactured.

The research will eventually extend beyond X-rays when the maximum expected 256Mbyte chip is achieved, the limit to which X-ray techniques are likely to go.

Ed.
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8/C1

1/C1

2/C1

4/C1

2/C1

1/C1

2/C1

1/C1

4/C1

6/C1

8/C1

2/C1

1/C1

5/C1

1/C1

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1/C1

1/C1

2/C1

1/C1

2/C1

1/C1

2/C1

1/C1

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PRACTICAL ELECTRONICS JANUARY 1989

23
The text appears to be a catalog or list of items for sale, possibly related to electronics or hardware. It is written in a dense, technical style, with a lot of abbreviations and codes for different products. The text includes descriptions of various items such as motors, power supplies, speakers, and electronic components, along with specifications and prices. The text is formatted in a list format, with each item numbered and described in detail. The list is quite long and the specific content is difficult to summarize without a detailed reading of the entire text. The overall theme of the document is technical and focused on hardware and electronic components.
We are all used to the twinkling of the lights on the Christmas tree during the festive season but wouldn’t it be nice to add a little more sparkle to other decorations? The circuits described in this article do just that. You can choose between angels with rotating halos, Rudolph with a flashing nose, pulsating stars, candles which flicker or a random circuit to liven up your decorative plum puddings, holly bunches or miniature Christmas trees. In fact the extent of what you can do is limited only by your ingenuity.

The circuits are designed so that you have a choice of outputs. You can use standard leds, high current-high intensity leds or even les or mes bulbs. This makes the circuits suitable for use in the home or in a big hall.

**RUDOLPH’S NOSE**

This is the simplest of the circuits and is suitable for flashing off and on any single dc load. It may be used to make Rudolph’s nose flash or to control a number of leds or even les or mes bulbs. This makes the circuits suitable for use in the home or in a big hall.

**RUDOLPH’S NOSE**

**RESISTORS**

| R1 | 5k6 |
| R2 | 2k3 |
| R3 | 1k  |

All 1/4 watt 5%

**POTentiOMETER**

VR1 250k min horiz preset

**CAPACITORS**

C1 100µF 10V electrolytic
C2 10µF polyester

**SEMIConDUCTORS**

TR1 TIP31A
IC1 555 timer bipolar or cmos type

**MISCELLANEOUS**

LP1 6V mes bulb
B1 9 volt battery (PP9 or similar) and connector

The output from the 555 timer is only really sufficient to drive a very small load, such as a single led. For most applications this will not be sufficient, so a driver transistor (TR1) and bias resistor (R3) have been included in the circuit. To allow a substantial load (up to 1A) to be driven a TIP31A power transistor has been selected. In this circuit R3 acts as a current limiter to prevent the current flowing through the base/emitter junction of TR1 rising above a safe level. When the voltage at the output (pin 3) or IC1 rises to VSS a current flows-through both R3 and the base/emitter junction of TR1. This causes TR1 to conduct and a current is therefore made to flow through the load and the collector/emitter circuit, thus energising the load.

If your application only requires the circuit to drive a single led output then the driver transistor and bias resistor can be omitted. The circuit is modified by reducing the value of R3 to 380 ohms and connecting the led in place of TR1. The anode of the led replaces the base, and the led’s cathode replaces the emitter connections of TR1 on the pcb.

**THE ANGEL’S HALO**

The Angels Halo and Pulsating Star circuits are both basically simple ten way chaser circuits, with different output sequences. The diagram for the Angel’s Halo circuit is shown in Fig. 2. This project is the standard ten way chaser, consisting of a 4017 counter, clocked by a standard 555 astable timer. As with Rudolph’s nose, the timing pulses are generated by IC1 which is a 555 cmos timer configured in the astable mode. Here again the frequency of the output pulses is governed by the values of VR1, R1, R2 and C1. VR1 has been deliberately made a large value so as to make the circuit adjustable through a wide range of speeds, although in practice the effect is at its best when the circuit is running fairly fast, so C1 has been made a fairly small value. Note that this circuit, and all of the following projects, must be constructed with a cmos 555 timer, the bipolar version is not suitable.

The clock output from pin 3 of IC1 is connected to the CP0 input of the 4017 counter IC2. The CP0 and MR inputs of IC2 are kept at the logic 0 state, by being connected to 0 volts, which causes the counter to advance at every clock pulse output from IC1. This causes each of the outputs Q0 to Q9 of IC1 to be raised to the logic 1 state in turn. These outputs are then connected to the base of the appropriate driver transistors (TR1-10), via a bias resistor (R3-10). The transistor driver circuit operated in the same manner as is described...
CHRISTMAS FLASHERS

Left to Right: Fig.2. Angel's halo chase. Fig.3. Candle flicker. Fig.4. Random pudding.
FLICKERING CANDLE
across the led to the correct voltage for the circuits, determined by the values of RI, R2 into a latch and displaying the output. loading the output from a fast running clock R13 - R22 RESISTORS
ANGELS HALO
above, energising the leds 1 to 10 in turn. The series resistors (R11-19) are included in the circuit to lower the voltage present across the led to the correct voltage for the devices specified and restrict the current flowing through the specified, safe level.

FLICKERING CANDLE
The next two projects are based on random circuits which use the technique of loading the output from a fast running clock into a latch and displaying the output. The candle flicker uses the circuit shown in Fig. 1. IC1 is half of a 556 dual cmos timer which is configured in the astable mode, to provide a high speed clock output. The frequency is, as for the previous circuits, determined by the values of R1, R2 and C1. In this application the values of these components are not critical, although they should be of the same order of magnitude as those specified. The pulses generated by the high speed clock circuit are fed into the CP1 input of IC2, which is a 4017 counter. The CP0 and MR inputs of this counter are held at 0 volts and the circuit thus counts up, in binary, at high speed, forcing the outputs Q0 to Q3 to the Logic 0 state. This difference between the two circuits is achieved by the inclusion of a 4028, 1-of-10 decoder (IC4). The outputs from the latch (IC3) are taken, again in an order which makes the design of thepcb easy, to three of the inputs (I0 to I9) of IC4. Input I0 of IC4 is permanently held at the logic 0 state by virtue of being connected permanently to 0 volts. In this arrangement only one of the outputs, I0 to I7 of IC4 will be at the logic 1 state at any moment in time. The output so energised is determined by the value of the binary number present at the inputs I0 to I7 of IC4. As input I3 is at the Logic 0 state this value can never exceed 0111 (decimal 7). The driver circuitry connected to the outputs of IC4 is identical to that for the previous circuit.

PULSATING STAR
The circuit for this project is shown in Fig. 5. As with the other projects the first part of the circuit is a cmos 555 timer, configured as an astable. The clock output from IC1 is used to advance the 4017 counter as described above. In this application we require a different type of output sequence with which to control our output drivers to that required for the Angel's Halo. To achieve this the outputs Q0 to Q6 of the counter are connected to the six output drivers

RANDOM PUDDING
This circuit is a variation of the circuit used for the Flickering Candle, and is intended for use in decorative Christmas puddings (with the leds being the plums), holly bunches (with led berries) or minature illuminated Christmas trees with random flashing lights. Alternatively a number of these circuits could be used to give a twinkling star effect as a background for a Christmas Crib or flying Rudolph.

The circuit diagram for this project is given in Fig. 4. The circuit is identical in operation to that of the Flickering Candle except that only one output is energised at a time. This difference between the two circuits is achieved by the inclusion of a 4028, 1 of 10 decoder (IC4). The outputs from the latch (IC3) are taken, again in an order which makes the design of thepcb easy, to three of the inputs (I0 to I9) of IC4. Input I0 of IC4 is permanently held at the logic 0 state by virtue of being connected permanently to 0 volts. In this arrangement only one of the outputs, I0 to I7 of IC4 will be at the logic 1 state at any moment in time. The output so energised is determined by the value of the binary number present at the inputs I0 to I7 of IC4. As input I7 is at the Logic 0 state this value can never exceed 0111 (decimal 7). The basic circuit is Fig. 5. As with the other projects the first part of the circuit is a cmos 555 timer, configured as an astable. The clock output from IC1 is used to advance the 4017 counter as described above. In this application we require a different type of output sequence with which to control our output drivers to that required for the Angel's Halo. To achieve this the outputs Q0 to Q6 of the counter are connected to the six output drivers

PRACTICAL ELECTRONICS JANUARY 1989

| ANGELS HALO | CANDLE FLICKER | RANDOM PUDDING |
| RESISTORS | Resistors | Resistors |
| R1 | 5k6 | R1 | 47k | R1 | 47k |
| R2 | 3k3 | R2 | 1k | R2 | 1k |
| R3-R12 | 82k | R3-10 | 82k | R3-R10 | 82k |
| R13-R22 | 390 ohms | R11-19 | 390 ohms | R11-R19 | 390 ohms |
| All 1/4 watt 5% | All 1/4 watt 5% | All 1/4 watt 5% |
| POTENTIOMETER | POTENTIOMETER | POTENTIOMETER |
| VR1 | 250 min horiz preset | VR1 | 250 min horiz preset | VR1 | 250 min horiz preset |
| CAPACITORS | CAPACITORS | CAPACITORS |
| CI | 1uF 10V pcb electrolytic | CI | 10uF polyester | CI | 10uF polyester |
| C2 | 2.2uF 16V tantalum | C2 | 100uF 10V pcb electrolytic | C2 | 100uF 10V pcb electrolytic |
| SEMICONDUCTORS | SEMICONDUCTORS | SEMICONDUCTORS |
| LED1-LED10 | high brightness leds, yellow | LED1-LED8 | high brightness led, yellow | LED1-LED8 | high brightness led, yellow |
| TR1-TR10 | ZTX 300 | TR1-TR8 | ZTX 300 | TR1-TR8 | ZTX 300 |
| IC1 | 555 cmos timer | IC1 | 556 dual cmos timer | IC1 | 556 dual cmos timer |
| IC2 | 4017 counter | IC2 | 4520 dual binary counter | IC2 | 4520 dual binary counter |
| MISCELLANEOUS | MISCELLANEOUS | MISCELLANEOUS |
| B1 | 9 volt battery & arid connector | B1 | 9 volt battery & arid connector | B1 | 9 volt battery & arid connector |
| 11 way ribbon cable to connect pcbs | Connector | Connector |

Components lists refer to the versions illustrated in the main circuit diagrams (Fig. 1 to 5). Refer to Figs. 6, 7 and 7a for other versions of circuits.
circuit, via D1 to D8, so as to cause the six outputs to be energised in the order -
O1, O2, O3, O4, O5, O6, O7, O8, and so on, with the sequence repeating ad infinitum.

This gives a backwards and forwards sweeping effect to the outputs, which are fed, through the respective dropping resistors, to the base of the transistors TR1 to TR6, which operate as described above.

In this project the LEDs (or other output indicators) must be driven via transistor current amplifiers since the load would otherwise exceed the recommended maximum current which may be drawn from the outputs of the 4017. The component values given in the circuit diagram are those required for high brightness LEDs. If your application requires normal LEDs with a current of 10mA the component values should be altered so that R3=68k, R4-R8=82k, R9=330 ohms and R10-R14=150 ohms.

The LEDs (both types) or bulbs are arranged as shown in Fig. 12 to form a series of spokes centered on LED1 and are driven in such a way that they produce a pattern which pulses in and out of LED1 which acts as a central point.

**ALTERNATIVE OUTPUTS**

The outputs shown in all of the circuits given above (except for Rudolph’s Nose) are designed to accommodate high brightness LEDs with currents too great for them to be directly driven from the outputs of the CMOS ICs specified. CMOS devices are limited to 100 mW power dissipation per output or a total dissipation of 500 mW per IC. It is therefore necessary to use the simple transistor driver circuits shown when the circuits are used to drive more than four standard LEDs (drawing a maximum current of 10 mA each). It is however possible to use devices other than high brightness LEDs for the outputs of the circuits shown above providing that a few modifications are made.

**LOW POWER LEDs**

If, for your application, you only need to drive a single LED, with a maximum current of 10 mA from each output, with no more than five LEDs on at any one time then the LEDs can be driven directly from the outputs of the CMOS ICs without the need for a driver transistor. Modification of the circuit is a simple matter since it is only necessary to change the transistor bias resistor (typically

---

Fig. 5. Pulsating star circuit diagram

---

Fig. 6. (above) Direct drive circuit for standard LEDs

Fig. 7. (right) Transistor driver circuit for 6V bulbs
CHRISTMAS FLASHERS

Fig. 8. Transistor driver circuit for 6V bulbs replacing LEDs in pulsating star circuit

82k) to the 330 ohm LED current limiting series resistor and connect the LED in place of the base and emitter connections of the ZTX300, as shown in Fig. 6. This modification may be used for all of the circuits given except for the Pulsating Star Circuit. (If low power LEDs are used in this project then the component values should be altered to those given in the circuit details for the Pulsating Star.)

The printed circuit boards for all of the projects have been designed to accommodate both of the above variations.

GREATER LOADS

If you want to get really adventurous an even greater DC load could be driven by replacing the ZTX300 transistor with an output circuit such as that shown for Rudolph's nose, but the PCB design will also have to be altered. Indeed it is perfectly feasible to use a relay with mains contacts, switching mains voltage bulbs, in place of each of the output LEDs/bulbs in each of these circuits, but by then you are getting into the High Street Illumination league.

CONSTRUCTION

The control circuits for all of the projects are built on the appropriate printed circuit boards, for which the foil patterns and the component layouts are shown in Figs. 9 to 15. It is anticipated that the LEDs or other output devices will be placed in holes drilled in appropriately shaped pieces of plastic or wood cut to shape, but foil patterns are also given for display PCBs for the Angel's Halo and Pulsating Star projects.

The foil patterns should be transferred to suitable boards which are then etched and drilled in the usual way. The components can then be inserted into the board and soldered in place. Although this process can be carried out in any convenient order, you will find that it is easier to perform this task if the components are inserted in ascending order of size. All the components of a particular size should be soldered into position before going onto a larger size of components. Care should be taken to ensure that polarity sensitive components are inserted into the board the correct way round.

The ICS are best accommodated in sockets MES OR LES BULBS

For a brighter display, perhaps in a larger room, such as a school or church hall you might wish to replace the LEDs with small-bulbs. This is simply achieved for all of the circuits by altering the values of the resistors in the driver circuit and the driver transistor to those shown in Fig. 7 (see Fig. 8 for the replacement driver circuit for using six bulbs in the Pulsating Star project.)

The printed circuit boards for all of the projects have been designed to accommodate both of the above variations.

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Fig. 9. (above) Rudolph's nose PCB layout

Fig. 10. (right) Angel's halo control PCB layout

Fig. 11. (Top right) Angel's halo display PCB

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CHRISTMAS FLASHERS

which are soldered in place along with the other components. The ics should be inserted as the last task before testing out the unit.

WIRING UP
Most of the pcbs have been designed in such a way that it is possible to mount the leds or bulbs directly on them for testing the circuit but this will not produce an effective display (except in the case of the two special display boards). It is anticipated that constructors will wish to place the output indicators in an appropriate place on the decoration and to connect them to the appropriate points on the pcbs with wires. The boards are best not wired up until all the components, except for the ics, have been inserted and soldered. The ends of these wires must be prepared by tinning before soldering into place. On/off switches have not been included in the designs since it was felt that it would be easy enough to simply connect and disconnect the battery, but if a switch is required it is a simple enough matter to include one in series between the battery positive connection and the pcb.

TESTING
Once all the connections have been made the boards should be carefully checked before inserting the ics and testing the unit. The ics should then be inserted into the correct sockets, taking care to ensure that they are the correct way round.

The circuit can then be tested by connecting the battery and ensuring that the circuit works as described.
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One of the main themes of this series is that it is not only possible but really easy to join together lots of little black boxes to make bigger black boxes. In other words, we work with simple logic modules that can be put together in hundreds of different ways to build an enormous variety of electronic systems. The electronic systems may range in complexity from a door buzzer circuit to a computer. If we are to be able to use the computer, we must know how modules can be joined to each other. This is what it means by this month’s topic, interfacing.

We shall deal with all kinds of interfacing except one particular field — interfacing electronic circuits to microcomputers. That will form the subject of a later part of this series. The subject of interfacing has lots of minor details about it that are not really worth remembering. Read the paragraphs below to get the gist of the subject, then keep this article handy for reference when you actually have a project to design.

If we are simply interfacing one logic gate to another gate of the same series, then a length of wire will do the trick. Though even, in this clear case, there is something to think about. Electric current travels fast, but logic gates are fast too. If the wire connecting one gate to another is too long, the delay while a high or low pulse travels along the wire may be sufficient to upset the operation of the system. So an important rule is to keep connections as short as possible. Avoid having wires longer than 500mm. This also reduces possible problems due to electromagnetic effects causing spikes to be generated in the wires. Later in this article we see what to do if wires must be long, when you are transmitting data from one room to another, for example, or controlling a robot.

If any logic circuit needs more than about three ics, it seems an inescapable law that you will not be able to power the ttl ics at 5V, and the cmos ics at another voltage. This could be preferable if the cmos ics are to be connected to other ics which won’t work at 5V. Fig. 2 shows ways of handling this. When connecting ttl to 4000 series, the ttl ic must have an open collector output. Usually the output stage of a ttl gate has an active pull-up. This is to pull the output voltage up when the output is supposed to be ‘high’ (Fig. 3a). But a high output from ttl is normally only about 3.4V, which is not high enough to drive a cmos ic working at 10V. With an open-collector output (Fig. 3b) there is no pull-up circuit on the chip. The collector is left open for a pull-up resistor to be connected externally. The pull-up resistor is connected to the higher voltage, such as the 10V supply voltage of the 4000 series gate (Fig. 2a). A high output from the ttl gate now produces an input voltage high enough to affect the cmos gate.

The most generally used open-collector buffers are the 7406 (NOT, or inverting gates) and 7407 (TRUE or non-inverting gates). The resistor can be connected to any external voltage up to 30V. Such outputs are also useful for driving other

---

**Fig.1.** Interfacing logic systems, all at 5V.

- TTL, they need a regulated 5V supply so, if a circuit has any of these in it, it is usually more convenient to run all the logic at 5V.
- We sometimes need a pull-up resistor when joining one gate to another of a different series. Fig. 1 shows when this needs to be done. The triangles represent ‘any gate’ in the series. Pull-up resistors are needed because the high output voltage from standard or LS ttl is not quite high enough to be recognised by HCT ttl or the 4000 series. A straightforward wire connection can be used for other interfacing, such as cmos to ttl, standard ttl to HCT ttl, etc.

**Fig.2.** Interfacing logic series when TTL is at 5V and CMOS is at a higher voltage

(a) Supply: +5V
(b) Supply: +10V

**Fig.3.** Output stages of (a) active pull-up and (b) open-collector TTL
devices, such as lamps, that work on voltages greater than 5V. There are also ttl NAND, NOR and AND gates with open-collector outputs. Gates of this type are often referred to as buffers because their main function is not to perform logic but to act as an interface between parts of a circuit that have different characteristics.

The cmos 4050 buffer in Fig. 2b is powered from the 5V supply, so it is compatible with the ttl gate that follows it. Its input stage is specially designed to accept input voltages up to 15V without suffering damage. This means that it can take its input from a cmos gate running on a 10V supply.

FANOUT

This is the number of logic inputs that can be fed from a single logic output. In most circuits this creates no problem since it is not often that we want to drive more than two or three inputs from one output. In any case, cmos inputs (4000, HC ttl, or HCT ttl) draw virtually no current and fanout is unlimited. Actually, in a 4000 series circuit, fanout is limited (to 50 gates), but this is not likely to worry you very often!

There is more about buffers and tri-state outputs later. Input pins of certain ic's may be connected to more than one logic input on the chip. Examples are clock, set and reset inputs of flip-flops, which may be equivalent to two ordinary inputs.

Fig.4. Light sensitive circuit

REAL WORLD INTERFACING

Interfacing logic to logic is fine but we need real-world interfacing if our system is to be of practical use. In other words, the system must have input and output sections. We consider real-world input first.

The most obvious real-world input interface is the press-button, switch or key, by which we tell a circuit what we want it to do. The interfacing may consist of just the button, switch or key by itself, though it may be preferable to de-bounce it. Module 4 (Oct 88) is a good example of such an interface.

Fig.5. Breadboard layout of circuits for Figs. 4 and 6.

In a previous article we described a security system that operates only by day. It needs a light-sensitive input stage. There are various ways of building this sort of interface. One way is shown in Fig. 4. Let's find out how it works.

Investigation 1

Light-sensitive interface

The interface has a light sensor, consisting of a light-dependent resistor (ldr) alternatively known as a photoconductive cell (pcc). Ldrs (or pccs) are made of cadmium sulphide. This is a semiconductor material, the resistance of which depends on the amount of light falling on it. Resistance is high in darkness or low light, but is much less in bright light. We make use of this fact in the light-sensitive interface.

1. Connect the circuit as shown in Fig. 5. For the present do not include the components on the lower half of the board (IC1, D1, R3), which will be added later.
2. Cover the ldr with a small box (or you hand) to keep light away from it.
3. Switch on the power. Read the meter.
4. Gradually remove the box (or your hand), do that an increasing amount of light falls on the ldr. Watch how the meter reading changes.
5. What is the meter reading when the ldr is fully exposed?
6. Gradually replace the box (or your hand). Watch how the meter reading changes.

What is happening is that the resistance of the ldr falls gradually as the ldr receives more light. The ldr (R1) and the fixed resistor (R2) act as a potential divider. As the resistance of R1 falls, the voltage at the junction between R1 and R2 rises.

This interface gives us an output voltage that varies according to the amount of light. Now we need to arrange for this to have an effect on a logic gate. Add IC1, D1 and R3 to the breadboard, to make the circuit shown in Fig. 6. The figure shows the connections if a 4011 ic is used to provide the gate. The inputs to the unused gates are connected to +5V (pins 5, 6) for reliable action. If you are using ttl, the pins to be connected to 5V or 0V are 4, 5, 9, 10, 12 and 13 (as in Fig. 8).

The output level from the gate is indicated by the led (D1), but you could use a logic probe instead. Now to continue with the investigation.

7. Vary the amount of light falling on the ldr. What happens to the output? When is the output low? When is the output high?

Interfaces to design

(Comments on p. 41)

1. Design a light-sensitive interface that has a low output in the light and a high input in the dark.
2. Design a light-sensitive interface that has low input in the dark, high input in the light, and that can be adjusted to change from low to high at any given light level.

IMPROVING THE INTERFACE

The interface described above gives a good clear response if the light level is distinctly weak or distinctly strong. What happens when it is in-between? For example, if the level of light is increasing slowly as the sun rises, there are in-between light levels which are neither weak nor strong. What is the interface to do at these levels?

We can decide on a particular threshold light level and say "If it is darker than this, it is night - the interface must have a low output. If it is as bright or brighter than this, it is day - the interface must have a high output."

Fig.6. Light sensitive input interface
PHOTO-TRANSISTOR SENSOR

This is another sensor used for detecting light. In Fig. 7 it looks as though we have forgotten the base connection, but it is not necessary to supply current to the base of a phototransistor. When light shines on the transistor, charge carriers are produced in its base region. The effect is the same as if a current is flowing into the base region. The brighter the light, the bigger the effect.

Increasing the light has the same effect as an increased base current.

As in an ordinary transistor, increasing the base current increases the collector current. So the final effect of increasing the light is to cause an increased collector current to flow. The current flows on through VR1. The bigger the current the bigger the voltage developed across VR1. We tap this voltage at any required level by adjusting the wiper of VR1. This is the upper threshold voltage developed across VR1. The bigger the current the bigger the voltage.

In Fig. 7 it looks as though we have a phototransistor and a Schmitt trigger gate. The meter is used for investigating the action of the gate.

CHOOSING LIGHT SENSORS

The ldr and the phototransistor work in different ways, but with the same effect — a change of voltage. An important difference between them is that the phototransistor responds more rapidly than the ldr to changes in light level. With a slowly changing light level, such as sunrise, the ldr is fast enough. But, if you have to detect a sudden and short-lived change such as the momentary breaking of a light-beam, an ldr may not have time to respond before the light is restored to its high level again. For applications such as these, which include detecting a racing-car passing the winning post or articles moving along a conveyor belt, the phototransistor has the advantage. Its response time can be further reduced by

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connecting its base terminal to the positive supply through a resistor of high value. This provides a small steady base current which puts the transistor into readiness for sudden changes in the amount of light falling on it.

Another sensor that has several applications is the photodiode (Fig. 9). It is usually connected as shown, so that it is reverse-biased. You might think that nothing would happen, because a reverse-biased diode is supposed to prevent current from flowing. However, there is a current flowing, the leakage current. This is small but, if it goes on to flow through a high resistance, a sizeable voltage appears across the resistor. In bright light, the leakage current of the TIL100 is around 15µA. The voltage developed across the resistors is:

\[ V = IR = 0.000015 \times 200000 = 3V \]

By choosing a suitable resistor, or using a variable resistor, we can arrange to obtain a voltage suitable for triggering a gate at a given light level. The TIL100 photodiode has a large sensitive area and is particularly sensitive to infra-red. It has many applications, including remote-control systems and intruder detection.

Investigation 3
Infra-red interface
Investigate the behaviour of the TIL100 photodiode as in Investigation 2, using a bench lamp as a source rich in infra-red radiation.

TEMPERATURE SENSOR
The most useful device for sensing changes in temperatures is the thermistor. This is made from a resistive material, the resistance of which changes markedly with change in temperature. Two kinds of thermistor are available. Those with positive temperature coefficient (ptc) have increased resistance as temperature increases. Those with negative temperature coefficient (ntc) have decreased resistance with increased temperature. The latter type is used in the next investigation.

Investigation 4
Temperature-sensitive interface
A range of ntc thermistors is available with different resistances at room temperature (25°C). The type chosen for this investigation has a resistance of about 47k. It is usual to connect the thermistor cool. Does the led immediately come on? Does it ever come on? (p. 41).

ANALOGUE INPUTS
We have confined our discussion and investigations to binary inputs. For example, we have thought of light levels as being 'high' (sunny) or 'low' (night). The TIL100 provides a digital output to trigger a logic gate when a light level or temperature exceeds certain thresholds. These are the interfaces that make something happen in the real world. One of the simplest of these is the humble led. We have used this frequently to indicate what is going on in the logic circuit. It does not do much except please you or annoy you, depending on what you expected it to do!

In practical applications of digital electronics we use output interfaces to drive devices such as lamps, motors, sirens, bells, solenoids, heaters - all of which are electrically-powered. Driving these devices is a matter of switching them on or off as required. Controlling the brightness of lamps or the speed of motors is usually a matter for analogue output circuits which, as stated above, will be described next month.

Fig. 10. Temperature sensitive interface

\[ V = IR = 0.000015 \times 200000 = 3V \]

By choosing a suitable resistor, or using a variable resistor, we can arrange to obtain a voltage suitable for triggering a gate at a given light level. The TIL100 photodiode has a large sensitive area and is particularly sensitive to infra-red. It has many applications, including remote-control systems and intruder detection.

Fig. 11. Output interfaces: (a) direct logic device, (b) open-collector output, (c) transistor switch, (d) Darlington switch.
is because of the strong back emf that the coil generates when the current in it is suddenly switched off. The back emf may be several hundred volts, it produces large currents through the transistor in the wrong direction and possibly destroys it. The protective diode conducts such currents safely away. Use it in circuits for driving electric bells, relays, motors and solenoids.

Fig. 12. Line driving with TTL

Although the transistor may be able to cope with these currents, it may burn. A logic gate is unable to provide sufficient base current to switch the transistor. This is often the problem with power transistors, which usually do not have such a high current gain as the low-power transistors. The 2N3055, for example, has a current gain of only 45. If we are trying to switch a motor requiring 5A, the base current to the power transistor must be at least 111mA. Obviously no logic gate could supply a current of this magnitude. In this case we use two transistors, connected as a Darlington Pair (Fig. 11d). TR1 can be a high-gain low-power transistor, and TR2 is a low-gain high-current transistor. The gate supplies a small base current to TR1. The collector current of TR1 is (say) 200 times larger than this, and becomes the base current of TR2. The gain of TR2 might be 50, giving an overall current gain of 10000 for the pair. Only 0.5mA is required from the gate to drive a current of 5A through the load.

Another way of switching is to use a relay. Use any of the circuits in Fig. 11, with the relay coil as the load. Apart from their being able to switch loads operating at high voltages (250V or more), an high currents (10A or more), relays are able to switch alternating current, including audio signals. This is something that the transistor switches described above can not do. Some relays can be energised directly from a ttl output, as in Fig. 11a. This type is often available in dll package like an integrated circuit, which makes it very convenient for mounting on the circuit board beside the logic ics. These low-power relays usually have lower voltage and current ratings than the larger types. If you use these, take care not to overload them as sparking may cause the contacts to weld together – and there's no way of getting inside the package to prise them apart!

The larger relays are best driven by making their coil the load of a transistor switch (Fig. 11c or 11d). This is the technique adopted for the relay of Module 8. Note the protective diode in the module. Some types of relay have a diode built in, but this type does not. With a suitable relay, you can interface to anything from a low-voltage lamp, an alarm bell, a radio set, an ac motor or an immersion heater to a ship's turbine or airport landing lights.

LINE DRIVING

If we feed the output from a logic gate into a long wire, the logic levels at the far end of the wire may be very different from those at the starting point. The gate may not succeed in driving the levels firmly high or low. Electromagnetic interference may generate voltage spikes on the line. Sudden changes of voltage may be reflected back from the far end of the line. We can reduce the electromagnetic effect by twisting the signal wire and the 0V wire around each other. This is known as a twisted pair.

We can improve the reception of logic levels at the far end by using special buffer gates designed for line driving and line receiving. Fig. 12 shows a way of driving and receiving, using ordinary ttl gates. The driver is any standard ttl gate, such as the NAND gate illustrated. This is connected as a NOT gate, so it inverts the original logic level. Connection to the receiving ic is by way of a twisted pair of wires. At the receiving end the input of the Schmitt trigger gate is held ready to move up or down according to the signal arriving along the line. The Schmitt trigger input helps to ensure that minor changes in voltage, caused by interference, have no effect on the gate. The gate is a NOT gate, so it inverts the logic level back to the original state. This method of line driving is not as reliable as using specially-designed line driving ics but is satisfactory for many purposes.

TRI-STATE OUTPUTS

This name is a bit of a puzzle, since it sounds as if we have a new type of logic with three possible states. Could they be 'high', 'low' and 'your guess is as good as mine'? No, there are only the two usual states 'high' and 'low'. The third state is 'mind your own business'. In other words, in the third state, the output of the logic circuits inside the ic is disconnected from the output pin of the ic and you can't tell what the output is. A more technical way of saying this is that the third state is high impedance.

Gates with three-state outputs are very commonly used in computers and other microprocessor-based circuits. In these, it is necessary to transfer data from one part of the circuit to another. For example, in a computer we may need to transfer data from:

- the memory to the microprocessor,
- the microprocessor to the memory,
- the disc drive to the memory,
- the microprocessor to the printer,
and many other transfers too. We could have several sets of wires - one set for every data transfer to be made. But we usually need at least eight wires for data transfer. The interior of the computer would soon begin to look even more like a bird's nest than it does already. The solution is to have just one set of connections, the data bus, to which all the parts of the computer are connected. Fig. 13 shows a data bus (only four lines to make the drawing simpler). This has four devices attached to it - these might be the output or input stages of the memory, the microprocessor, the disc drive or the printer. Device A, B and C all have outputs connected to the bus. These are 'talkers'. They put data on to the bus. Device D has inputs connected to the bus. It is a 'listener'. It reads the data that is present on the bus.

D can receive data from A or from B or from C. The important thing is that A, B
and C must not all talk at once. This is where the TRI-state outputs are used. The outputs of the gates in devices A to C are all three-state outputs. When a device is not supposed to be putting data on the bus, its outputs are switched to the high impedance, or disabled state. The logic of the computer control circuit is such that only one device is enabled to put data on the bus at any one time. D listens happily to one talker at a time, without being confused.

**TEST YOURSELF**

*Answers on p. 41*

1. Which gate-to-gate interfaces need a pull-up resistor?
2. What happens to the resistance of an ldr when the amount of light falling on it is reduced?
3. How many standard ttl gates can be driven from an HC ttl output?
4. What kinds of sensor can be used in a light-sensitive input interface? Which would you choose for the fastest response?
5. What is the difference between a ptc thermistor and an ntc thermistor? Which sort did we use in the temperature sensitive interface?
6. In Fig. 10, what is the effect on the input voltage of the gate as the temperature increases? What is the effect on the output voltage?
7. Which of the circuits of Fig. 11 would you use for interfacing to:
   (a) an electric fan driven by a 240V ac motor.
   (b) a beacon operating at 12V dc and requiring 4A.
   (c) an audible warning device on a washing machine, operating at 6V dc and taking a current of 10mA.
   (d) a small dc motor on a robot, operating at 3V, 250mA and able to be reversed by reversing the current.
8. What is the third state of a three-state output and where is it most often used?

**MODULES OF THE MONTH**

**7. Light Sensor**

This module (Fig. 14) is based on a ldr and is adjustable to trigger over a wide range of light levels. Output Q is high when the light is below the set level and is low when it is above. Output P is the inverse of output Q. The led shows the state of output Q. The ldr faces toward the top edge of the board, but can be mounted to face in other directions. It can also be connected on an extension lead if preferred. The module takes 6mA when the led is off, and 15mA when it is on.

**Parts required**

- R1: ORP12 light-dependent resistor (or similar type)
- R2: 180 ohm carbon or metal-film
- VR1: 1k preset resistor, miniature
- IC1: 74HC14, hex Schmitt trigger inverters
- D1: TTL209 or similar led
- SK1, SK2: pc terminal 2-way 14-pin dil socket

Stripboard Vero 14345

**8. Relay**

This module (Fig. 15) drives a relay from logical inputs. There are two inputs:

- L activates the relay when it receives a low input; if this input is not being used, connect it to the positive supply (+).
- H activates the relay when it receives a high input; if this input is not being used, connect it to 0V (0).

Both inputs may be used in a circuit - ie, the relay is activated if L is low OR H is high (or both). There is room on the board to substitute any small relay. The type specified is a reed relay with a normally-open switch which closes when the relay is activated. Another type in the same series has a change-over switch; substitute a 3-way terminal for SK2 if you are using this. The contacts of the specified relay are rated at 500mA, 200V dc, 10W, with a non-reactive load. This module takes 3mA when quiescent and 30mA when the relay is energised.

**Parts required**

- R1: 56k, carbon or metal film
- D1: 1N4148 silicon diode
- TR1: ZTX300 npn transistor
- IC1: 74LS02 quadruple 2-input NOR
- TRA1: encapsulated reed relay, form A (Electromall stock no. 348-970)
- SK1: pc terminal 4-way
- SK2: pc terminal 2-way
- 14-pin dil socket

Stripboard Vero 14345

**SYSTEMS OF THE MONTH**

Here are two systems that you can build using some of the modules described in previous months:

1. **Traffic lights (Fig. 16)**

   This is powered by Module 1, a bench PSU or a 6V battery. The timer is the programmable multivibrator (Module 5) set to run in astable mode at 0.5Hz. Its output drives the counter (Module 6) which runs through the following stages:

   **Count** | **Outputs** | **leds to be lit**
   --- | --- | ---
   0 | D C B A | 0 0 0 0
   1 | 0 0 0 1 | Red
   2 | 0 0 1 0 |
   3 | 0 0 1 1 |
   4 | 0 1 0 0 |
   5 | 0 1 0 1 | Red and yellow
   6 | 0 1 1 0 |
   7 | 0 1 1 1 |
   8 | 1 0 0 0 | Green
   9 | 1 0 0 1 |
   10 | 1 0 1 0 |
   11 | 1 0 1 1 |
   12 | 1 1 0 0 |
   13 | 1 1 0 1 | Yellow
   14 | 1 1 1 0 |
   15 | 1 1 1 1 |
To decode this output and make it switch the leds we need use only outputs D and C. This gives us the following logical statements:

Statement Logic circuit needed
Red is on when D=0 NOT D
Yellow is on when C=1 Drive yellow directly from C
Green is on D=1 AND C=0 D AND NOT C

Instead of using an AND gate for the green light, it is more convenient (though more confusing) to use NANDs:

\[
D \text{ AND NOT } C = \text{ NOT}(D \text{ NAND } \text{ NOT } C)
\]

This gives us the following logical statements:

- \(D = 1\) AND \(C = 0\) D AND NOT C
- \(D = 0\) NOT D
- \(C = 1\) NOT D

BUFFERS

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<th>Series</th>
<th>Number</th>
<th>Logic</th>
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<tbody>
<tr>
<td>ttl open-collector</td>
<td>7406</td>
<td>NOT (inverting)</td>
</tr>
<tr>
<td>CMOS 4000</td>
<td>4049</td>
<td>NOT (inverting)</td>
</tr>
<tr>
<td></td>
<td>4050</td>
<td>TRUE (non-inverting)</td>
</tr>
<tr>
<td></td>
<td>4502</td>
<td>NOT (inverting)*</td>
</tr>
</tbody>
</table>

* with tri-state outputs

DIGITAL ELECTRONICS

Comments

Interfaces to design

1. There are two ways of setting about this. One is to interchange the Idr and resistor R2 (Fig. 6). Make R2 larger (100k is suitable) to get the gate to change state at typical light levels. The other approach is to invert the output from the gate. Feed the output to a second gate in the same ic. This too has its inputs connected to make it act as a NOT (INVERT) gate. The output from this is the inverse of the output from the first gate, which is what is required.

2. The circuit is the same as Fig. 6, except that R2 is replaced by a variable resistor of low value, for example, 1k. The gate input is taken from the wiper of this resistor. The light level at which the gate output changes depends on the setting of this variable resistor.

Investigation 2

If the supply voltage is 6V, the lower threshold of the gate is approximately 2V. The upper threshold is approximately 2.8V. At step 6 the led does not go out immediately; you have to withdraw your hand until the voltage reaches the upper threshold. At step 8 the led does not come on unless the voltage falls below the lower threshold.

Investigation 4

At step 3 the led comes on, usually within a second if you have set the voltage close below the upper threshold. The slight reduction in resistance of the thermistor produces a slight rise in voltage, sufficient to trigger the gate to change state. The led does not come on when you take your fingers away. You need to cool the thermistor, perhaps by putting ice on it, to make the led come on again. This interface is suitable for a fire alarm system, but not for a thermostat. Why?
HOW TO USE PCB TRACK PATTERNS

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ISOdraft is available from Cannon & Wrin, 68 High Street, Chislehurst, Kent. Tel: 01-467 0935.

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Place positive transparency onto photosensitised copper clad fibre glass, cover with glass to ensure full contact. Expose to Ultraviolet light for several
minutes (experiment to find correct time – depends on UV intensity).

Develop PCB in Sodium Hydroxide (available from chemists) until clean track image is seen, wash in warm running water. Etch in hot Ferric Chloride, frequently withdrawing PCB to allow exposure to air. Wash PCB in running water, dry, and drill holes, normally using a 1mm drill bit.

(PCB materials and chemicals are available from several sources – study advertisements.)

* CAUTION – ENSURE THAT UV LIGHT DOES NOT SHINE INTO YOUR EYES. PROTECT HANDS WITH RUBBER GLOVES WHEN USING CHEMICALS.

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WEAPON'S LETTERS

LEDDING EDGE

Dear Ed,
I read with great interest Owen Bishop's Digital Electronics Pt. It's very informative and starts from the very basics. The Sept 88 issue of PE is the first one that I have seen and was one of the best electronics mags on the shelf - I eagerly await more issues.
I have a couple of queries, though. In the indicator module, why use ICl? cannot logic levels from any source be coupled, via resistors, straight to the leds? Secondly, why is a 120 ohm resistor used for led current limiting? With a psu line of 5V, it appears that over 40mA will flow through the led, in excess of its capabilities.
Keith Clapton, Oxon.

The indicator board is a general purpose module, and since some logic ics cannot supply the current necessary to drive leds, a more powerful buffer is required as an interface, hence ICl, which has more than enough output power available.
Since there is a drop of about 2V across the led, the equation is not 5V/120R, but 5V/120R, which equals 25mA. A good question!
Arthur Bloomer (ex G&ISO), Camborne.

METERING METAL

Dear Mr Becker
I am one of the very old school, from the days of swinging coil reactions and bright emitter valves; the days of fusing lead and sulphur in order to obtain crystals. I built my first receiver in 1922, including the making of coils, condensers and transformers etc.
I have just found your magazine - very interesting but a little strange to me, all those funny words!
The metal detector article in the July issue interested me so much that I have obtained the CS209 chip for it, but I have a couple of questions. Can I modify the circuit to include a meter, and if the voltage is increased to 18V will this improve the search range?
Sorry if this is elementary, but I am 77 years of age and have forgotten a lot.
Arthur Bloomer (ex G&ISO), Camborne.

We are delighted to hear your interests have crossed the years. I pass you over to Robert for the answers to your questions.
Ed.

For meter indication an inexpensive tuning meter of about 200μA to 250μA full scale deflection should suffice. It should be connected from ICl pin 4 to the positive supply rail via a 22k resistor and a 47k potentiometer connected in series. The pot is adjusted for the highest sensitivity that does not result in the meter being driven beyond full scale.
A higher supply voltage is unlikely to result in increased search range, but very careful adjustment of VR1 will optimise it.
Robert Penfold.

CALLING HEBAREK ZBADIA

Dear Sir,
I have received a letter from one of your readers, Mr Habeek Zbadia. Unfortunately he did not tell me his address and since he sent money with his letter I would like to contact him urgently.
Could you kindly appeal to him through your pages?
C. R. Brown,
7 Mayfield Drive, Buckley,
Clwyd, CH7 2PL.

It's amazing how frequently advertisers also come up against the problem of anonymity, especially when people illegally sign their letters without using block capitals.
Robert Penfold.

ULTRASONIC TAPE

Dear Ed,
I don't think anyone is interested in knowledge of one or two snags we came across while building Robert Penfold's Ultrasonic Tape Measure of March 87, and of our solutions to them.
The circuit and PCB diagrams differed in that R6 and R7 were interchanged as were R8 and R9.
We found the pulse width of the led too long, though the frequency was ok, so allowing two bursts of the 40kHz pulses and consequent resetting before an echo was received. A working solution was obtained by changing C3 to 20nF and R3 to 20M. This ensured only one burst. The counter clock frequency appeared to be twice what it should be, we changed R4 to about 560 ohms to correct this though we are concerned that this might affect its stability. We also found it necessary to widen the distance between transducers to 70mm. The Schmitt trigger signal appears noisy and we are considering a filter for this stage.
Arnold Collett,
Wolverhampton Poly.

A few people have encountered difficulties with this unit but the only known error was the swapped resistors, a fact reported in Points Arising. I no longer have the prototype and cannot check on the capacitor values, although a lot of previous checking brought no further errors to light. I do not understand the points about reducing R4, which would further reduce the pulse width from the led rather than affecting the counter clock frequency. Anyway, if anyone has difficulties it is worthwhile making the suggested mods to the IFO values.
Robert Penfold.

OMNIPOTENT

Dear Mr Becker
Please accept our latest catalogue which we hope you will find comprehensive enough to merit a mention in your “News and Marketplace” feature.
Our main business is in over-the-counter sales, but we are happy to say that the mail order side of our business is growing steadily. If customers try us and find that we rarely send out an incomplete order.

We would also like to take this opportunity to congratulate you on the way the magazine has developed over the past few years, it really has improved tremendously.
Janice Borthwick, Omni Electronics, 174 Dalkeith Road, Edinburgh, EH16 5DX.

Your catalogue is very comprehensive, and I was pleased to include a mention of it in the October issue. I hope your business benefitted from the additional publicity.
Thank you for your kind remarks about PE, we too really try to offer people what they want - I believe people respond to the personal approach.
We are pleased to mention any advertiser's catalogue on the News pages if we are sent a copy. Whether the catalogue is one page or a thousand is immaterial if the goods are of interest to our readers. Likewise, we shall be pleased to try to publicise details of any advertiser's new product or service, especially if accompanied by a suitable photograph. The News pages are a free, but valuable, shop window of which more advertisers should take advantage.
Ed.
A ctivity on the Sun is on the increase, and already there are suggestions that the next solar maximum may be at least as energetic as that of 1958-9, the most active on record. But has this anything directly to do with the weather we experience on Earth? Measurements carried out from the Solar Maximum Mission satellite (SMM) suggest that the Sun is actually brighter when it is most active. True, the difference is not very great — about 1 per cent — rather like the shape of the Moon a few days from full — and no telescope will show anything upon its brilliant surface apart from a few vague shadings now and then. However, if it really is launched in October, when Discovery performed almost faultlessly, is encouraging in every way. Astronomers are particularly delighted, because it means that if nothing else goes wrong we may hope that the outburst was underluminous by more than a factor of 10,000. Hubble Space Telescope will be put into orbit early in 1990. This is eagerly awaited — not least because the telescope itself has never been improved by the long delay; it was never built to endure long periods on the ground. However, if it really is launched in the first part of 1990, it should perform up to expectations. We may also hope now for more definite timings of other future probes, such as CRAFT (Comet Rendezvous and Asteroid Fly-by) and Cassini, the all-important mission to Saturn and its enigmatic satellite Titan.

First, however, will come the Voyager 2 pass of Neptune in August 1989. So far all is well, astronomers everywhere are watching its approach, and keeping their fingers crossed!

S U P E R N O V A N E W S

Astronomers are still hard at work analyzing the results from supernova SN 1987A, in the Large Cloud of Magellan. As we know, the progenitor star was not a red supergiant, but a blue one — which explains why the outburst was underluminous by

The Sky This Month

U sing December there are still several bright planets on view. Venus, in the morning sky, is of about magnitude -2.2, and is unmistakable even though it has started to draw in toward the Sun and will not rise until after 7am at the end of the month. It is gibbous, with a phase of over 85 per cent — rather like the shape of the Moon a few days from full — and no telescope will show anything upon its brilliant surface apart from a few vague shadings now and then. Mars remains in the evening sky. It is still brighter than any star apart from Sirius, but its apparent diameter has dropped to only about 10 seconds of arc at the end of December as compared with 23 seconds of arc at opposition last autumn. However, observations of it are still useful. Generally, Mars develops dust-storms when near perihelion, and one such storm has been expected, but at the time when I write these words (October 4) it has not developed, so that Mars, like the Earth, is having unusual weather! The south polar cap has now become very small. Jupiter reached opposition on 23 November, and is still excellently placed, moving on Taurus not far from the star-clusters of the Pleiades and the Hyades. It is above the horizon almost throughout the night, and this is an excellent time to look for the Galilean satellites. The remaining bright planets, Saturn and Mercury, are to all intents and purposes out of view this month. The Sun is becoming more active, which is more than can ever be said about Phobos 1, and while Discovery is back on course, we could wait a thousand years for U Scorpii to become spectacular.
supernova standards (a blue star has less surface area than a red one). There are also some other strange facts. The celebrated "Mystery Spot", 1/20 of a second of arc away from the centre of the outburst, now seems to have disappeared, and it is best to admit that we do not have the slightest idea of what it really was. Unless it reappears, we will have great trouble in finding out.

The neutrino observations have also been under scrutiny. The 19 neutrinos recorded by the 'water detectors' at Kamiokande in Japan and under Lake Erie seem unquestionably to have come from the supernova, and indicate that the mass of a neutrino of this kind really is negligible by any standard. However, the neutrinos reported from the Mont Blanc detector a few hours earlier seem definitely to have been spurious, and not associated with the supernova.

Meanwhile, when can we expect a new supernova in our Galaxy? We cannot tell - but we can hope. The best candidate is probably Eta Carinae, in the far south of the sky, which is an erratic variable - in the 1830s it outshone every star in the sky apart from Sirius, though for a century now it has hovered just below the limit of naked-eye visibility. Another is U Scorpii, a recurrent nova which has flared up in 1863, 1906, 1936 and 1979. Observations now indicate that a new outburst has occurred, so that the star rose from its normal magnitude of 18 to brighter than 11 for a few days. The outburst was discovered in 1987 by the South African amateur Danie Overbeek, and there are suggestions that U Scorpii may be a potential supernova. Unfortunately its distance is not known, and estimates range between 10,000 light-years to 200,000 light-years. It is a binary, so that if it does 'go supernova' it will be of Type I, whereas SN 1987A was, of course, of Type II.

We must wait and see. Watch U Scorpii; in a thousand years or so, or even before, it may provide us with something really spectacular!
In the last part of the PE Dual Beam 'Scope project, we describe the Y-input amplifiers and the beam splitter, and describe a number of useful functions for the 'scope.

So far, in the last two issues, we have powered up the tube and have the beam sweeping nicely across the screen face. Perhaps some of you have already had the trace going vertically as well — by turning the tube on its side! This month I'll show how the vertical trace is produced without trickery, by describing the two Y-input amps and the beam splitter. Then I'll give a few hints on using a scope.

There are two input amps, which are identical to one another and have been kept to a minimum of simplicity. Fig. 25 shows one of them. Consisting of switched passive attenuation and switched active gain stages they amend the input signal levels to meet the dictates of the screen display height.

The input signal comes in via the relevant input socket and is immediately presented with a choice of routes by S8. Signals with an ac content, ie, frequency signals, are decoupled by leaving S8 open and routing them through C21. For pure dc voltages, or ac signals with little or no dc bias, S8 is closed so bypassing C21. Where frequency signals may be imposed on a high dc voltage level, the dc is removed by opening S8 to interpose C21 in the path.

Following S8 is the attenuator selection switch S6a and a chain of three potential-dividing resistors. They nominally attenuate the input potential to one-tenth and one-hundredth. More precise resistor values could be substituted if exact division ratios are desired.

After S6a, ac signals pass through C22, but dc voltages meet R41, on the other side of which are DI1 and D12. This combination restricts the maximum voltages that can appear at this junction to approximately those of the power lines.

The working voltage of the standard polyester capacitors used in the prototype for C21 and C22 is 160Vdc. If voltages higher than this are to be probed, capacitors of a higher voltage rating should be substituted. The same also applies to C17 of the external sync input shown in part two.

Non-inverting opamp IC6 acts as a buffer and gain stage. The LM6361 suggested will handle frequencies well in excess of 3MHz. VR6 adjusts the dc output offset level. The LM6364 and LM6365 are equally suitable without circuit modification. Alternatively, a TL071 or TL081 could be substituted for IC6 (and for IC4), though they will only handle frequencies up to

---

Fig. 25 Circuit diagram of Y-drive amplifiers and beam splitter
about 150kHz and VR6 must be connected across pins 1 and 5 instead of pins 1 and 8.

For each of the two channels the output of IC6 is brought to S7, a single internal sync signal routing switch. This allows the time base sync trigger to be selected from either channel.

Following IC6, panel pot VR7 controls the signal level sent through one of the gates of IC5a-d, so that the deflection drive transistor TR4 and TR5. The action of TR4 and TR5 is similar to that of TR1 and TR2 of the X-drive, except that the offset deflection positioning is done by one of the two VR8 pots as selected by the control high, while holding the other gate pair closed by taking its control low. The inclusion of R30 and R31 prevent adverse loading of the outputs of IC3b. This method enables each Y-trace to be independently positioned vertically on the screen with respect to the other Y-trace.

With VR7 set for maximum level and with S6 on position 3, a 1V p-p input signal will give a vertical trace of approximately half the screen height.

**BEAM SPLIT**

In order to display two waveforms on the screen we simply insert an automatic changeover switch at the output of the two Y amps. We then constantly switch back and forth from one amp to the other. By applying slightly different dc biases, each Y trace can be independently positioned vertically on the screen with respect to the other Y trace.

The switching between the traces needs to be synchronised so that the changeover does not occur while the trace is already moving across the screen. The output of IC1b in Fig. 20 is taken to the input of flip-flop IC3b in Fig. 25. IC3b is wired so that the twin outputs produce opposing logic levels each time a pulse is received on the input. In other words, when one output goes high, the other goes low, and vice-versa.

Each time the output of IC1b goes high at the end of the sweep period, the pulse triggers IC3b into its next state. The control pins of the four analogue gates IC5a-d, are connected to the respective flip-flop outputs. Each gate opens when the control pin goes to logic 1, and closes for logic 0. Although digitally controlled, the open gates will allow analogue signals to pass through virtually unattenuated. Each pair of gate outputs are commoned and then fed to the respective Y-axis deflection drivers TR4 and TR5.

For most X-axis sweep rates the alternate switching between the Y amps will be sufficiently fast so that the traces appear to be occurring simultaneously. At very slow sweep speeds, of course, the alternate switching will be apparent.

Incidentally, I experimented with high speed toggling between Y amps during slow sweeps, blanking the sweep at the moment of transition between amps. This is a method used on commercial scopes with more expensive screens and circuitry. The characteristics of the tube used in this project, though, appeared incapable of allowing clean traces to be produced with this technique.

S5 is included to provide a choice of Y display modes. In position one, the dual mode is selected. In the next two modes just one trace is displayed, either Y1 or Y2. This is done by forceably opening one gate pair by holding the control high, while holding the other gate pair closed by taking its control low. The inclusion of R30 and R31 prevent adverse loading of the outputs of IC3b.

As an idea for experimentation, it is possible to split a single beam into more than just two traces. If two octal gates, such as 4051s, were to be used, eight traces could be displayed. In this case the gate selection would be performed by replacing IC3b with a binary counter. Connecting the first three outputs to the multiplexed control inputs of the 4051s, the latter can be cycled through each of their eight individual outputs. In reality, the circular three-inch screen of this scope is probably insufficiently large for eight traces to be usefully displayed, and the pcb would need modifying, but the technique could certainly be used for a larger rectangular screen.

S5 in position four diverts amp Y2 to the X-plates in place of the sweep generator. This enables Lissajous to be drawn, as discussed later.

**Y-BOARD ASSEMBLY**

Fig. 26 shows the component layout for the third printed circuit board. This pcb holds both Y-amps, the beam splitter circuit, and the Y-axis drive transistors.

Note that, as with the X-board, the pcb mounting rotary switches are soldered to the back of the board. Again make sure that the pins are satisfactorily soldered, and that the semiconductor and electrolytic capacitors are inserted correctly.

The remaining control pots, switches and sockets are shown in Figs. 23 and 24 of part two. Make all connections except for those to the Y tags of the tube base, and the +250V supply (pins 21-23).

Obervant readers may have noticed by now that not all consecutive component and...
connection numbers are used. True, on bench testing the prototype, it was found possible to simplify the circuit in some areas.

Y-AMP TESTING
With all ics inserted, temporarily connect the wipers of both VR8s to gates IC5a-b in place of the VR7 wipers. Monitor the junction of IC5 pins 2 and 3 on a meter, and check that with S6 in positions 2 and 3 the respective VRs will vary the output voltage up and down. Reconnect the VR7s and VR8s to their correct points. Now monitor the junction of IC5 pins 9 and 10 and check that with S6 in positions 2 and 3 the respective VRs vary the levels at this junction. Next set each VR8 for a slightly different voltage, switch the time base to a slow rate and check that pins 12 and 13 of IC3b toggle up and down. Again monitor IC5 pins 9 and 10, switch S5 to position 1 and observe that the gates are switching between the two VR8s.

Centre the X-trace on the screen, and switch off. Remove the two temporary Y-deflection pots referred to earlier in the article, and connect pcb pins 21-23 to their correct tube and ht points. Set VR9 for minimum resistance, switch on again and if necessary readjust VR11 so that the positive ht is at +250Vdc.

Switching between both channels, adjust the potentiometers VR12 so that the X-trace moves up and down the screen. With S5 on position one both traces should be seen to be independently variable.

You can now check the front end of each Y amp. First, connect each Y-amp input to 0V. Then monitor the junctions of each IC6 and VR7 in turn and carefully adjust the offset control VR6 so that a reading of 0V is present at all settings of S6.

Remove the input 0V temporary links and connect a lead between the 50Hz output and each Y amp input in turn. With S6 on position 3 and S8 open turn up VR7 until you see a vertical waveform on the screen. Set the synch switch S7 to the correct channel path and adjust the sync level pot VR5 until the trace stabilises. If necessary, select a different X-sweep rate with S1 and also adjust the variable sweep rate pot VR2. Switching the sync phase switch S4 up and down the waveform display should shift position by half a cycle.

Switching S5 to position one, the 50Hz signal should appear on one trace, while the other trace remains unmodulated. Connecting the 50Hz into the other amp will then swap the roles of each trace.

Temporarily couple the two Y amp inputs so that the 50Hz feeds both circuits simultaneously. Set both VR7s to maximum output level, switch both S6s to the same position whereby both screen traces are seen fully. Position each trace on top of each other and observe that their amplitudes are roughly equal to one another.

Finally, adjust the X-trace extends an inch or so to either side of the screen width, allowing latitude for VR4 to shift the trace to left and right.

FREQUENCY MEASUREMENTS
It is the rate at which the beam spot travels between two points that determines the calibration of a displayed Y-axis frequency. The number of times per second that the beam crosses the screen is irrelevant to this calculation. You can trigger the sweep just once per minute and still know that the distance between two waveform peaks represents a particular frequency.

The factor that governs the sweep rate across the screen is the rate at which the control voltage changes between two levels. If the beam takes precisely one second to cross one centimetre, during which time one complete waveform cycle is vertically displayed, the waveform frequency is 1Hz.

From this observation you know that if ten full cycles are shown within that 1cm, the frequency is 10Hz. If you increase the rate at which the sweep control voltage changes by a factor of ten, so that the sweep covers 1cm in 0.1 secs, then ten full cycles appearing within 1cm will represent 100Hz, and so on up the scale.

PERSISTANT SWEEPS
Although you need the beam to cross only for a given number of cycles per centimetre, it is advantageous to repeat the sweep as frequently as possible for two reasons. First, you obviously want to observe the monitored waveform long enough to make measurements and note how the waveform may change across a period of time. Secondly, a single sweep, especially when sampling high frequencies, is usually insufficient for the eye to adequately register the detail, even though image persistence may help.

One source of persistence is due to the human eye being capable of retaining an image on the retina for several tenths of a second, even after the original image source has disappeared. Another source is the tube itself since the fluorescent screen coating will also continue to glow for a brief period after the beam has passed. Indeed, tubes are manufactured in a variety of screen materials to offer different persistence rates. Despite these factors, unless the sweep is fast, the image still needs reinforcing at a frequent rate for it to be readily observable.

Hence the requirement for retriggering the beam at the earliest practical moment - it's usually so we can see the darn thing!

When switching between ramp rate ranges, ideally the rates should be matched multiples. The normal tolerances of the actual components used will inevitably result in imprecise ratio changes, though the variations can be corrected by adjustment of VR2. You could, of course, at greater expense, substitute capacitors of a more precise tolerance. You could also replace S1 by an RS Components' rotary switch kit with two 1-pole 12-way rotors and include intermediate capacitor values.

At the fastest switched ramp rate and with VR2 at minimum resistance, ten cycles of a 1MHz signal can be displayed. At the slowest setting and with VR2 at maximum resistance, the sweep takes approximately five seconds to cross the screen. The 50Hz reference generator can be used for low frequency calibration, though a signal generator with known outputs frequencies provides a better overall answer.

AMPLITUDE MEASUREMENTS
Whereas the horizontal deflection measurements represent time and frequency, vertical deflections represent voltage levels. The 50Hz generator is useful here as well. Once its output has been set to a known level, the relative screen positions of the vertical trace can be observed and adjusted by the VR6s so that amplitude is related to vertical displacement. DC voltage levels may also be monitored, when S8 is closed. First set the trace centrally on the screen, then probe the voltage source.

As I mentioned earlier, the precision of the attenuation and gain resistors will determine the uniformity between switched input
levels. You will also remember that the IC6 opamps have an offset correction control. Inevitably, even very small variations in the equivalent levels of the power supply will be reflected in the basic dc output level of the opamps. This will be further enhanced when gain is switched in, resulting in the deflection of the vertical trace. The precise setting of the VR6 offset controls will minimise the deflection when switching between gain ranges.

Within the bounds of the slowest sweep rate, there is no lower limit to the input frequency. The upper frequency limit of the LM6361 input opamps is well above 3MHz, though the characteristics of the tube and the simplicity of the Y-deflection drivers impose a lower top frequency limit. The observed signal amplitude decreases with frequency, with a usable maximum of about 2MHz, but beyond that the vertical signal trace becomes too small. When frequencies rise above about 500kHz, square waves will also increasingly be reshaped to triangle waves, as the frequency gets closer to the drive transistors’ gain limits.

DUAL BEAM MONITORING

One big advantage of seeing two traces on the screen is that comparisons between signals can be made. There are many ways in which the facility may be used, of which I’ll quote only a few, plus some general hints on scope use.

With one probe connected to the input of an amplifier the other probe can be used to follow the signal through the amp at various points. Comparisons of amplitude, phase shifting and shape changing are just some of the qualities for which you can look.

MATCHING OSCILLATORS

Two oscillators can have their fundamental or harmonic frequencies precisely matched by taking a probe to each and synchronising the sweep trace to one of them. By adjusting one of the oscillators, the relevant peak counts can first be corrected. Then when the rates are fairly closely matched it will be seen that the second trace moves in relation to the other. A forward movement indicates that it’s running faster than the primary oscillator, and vice versa. Carefully adjusting the rate in the correct direction, the relative movement will cease when both oscillators are running at precisely matched frequencies. The matching of crystal controlled oscillators for clocks is one obvious use.

If you were trying to match frequencies by moving a single probe from one oscillator to the other, you could never achieve this same degree of precision since you would be trying to see mere fractions of horizontal displacement between separate observations. However, you can use just one probe to achieve matching precision if you connect the external sync input to the primary oscillator, and vice versa. Carefully adjusting the rate in the correct direction, the relative movement will cease when both oscillators are running at precisely matched frequencies. The matching of crystal controlled oscillators for clocks is one obvious use.

If you were trying to match frequencies by moving a single probe from one oscillator to the other, you could never achieve this same degree of precision since you would be trying to see mere fractions of horizontal displacement between separate observations. However, you can use just one probe to achieve matching precision if you connect the external sync input to the primary oscillator, and then observe the second oscillator on the screen. Obviously, this method also applies to single beam scopes. With a dual beam scope, the same technique allows two oscillators to be observed relative to a third.

MONITORING DELAYS

Monitoring reverb or echo delay units is another ideal dual-beam function. By syncing one trace to the input, the other can monitor the delayed output and the screened distance between the original and delayed events measured, from which the delay time can be established.

Delays or displacements between logic signals can also be monitored, syncing on one and observing both. Switching to the opposing sync phase trigger is also beneficial in cases like this, effectively advancing or retarding the sync point by half a cycle.

Additionally, by opening the ‘bright-line’ switch S2, the situation occurring immediately after an infrequent event can be monitored. In this mode, the trace is synchronised to the infrequent event signal. In its absence the trace will remain untriggered and the screen stay dark. On receipt of the sync trigger the trace will start across and the signal from the second probe will be seen.

COMPARISON MARKER

Two probes can also be used in another fashion, to monitor comparative signal levels. One probe is used as the investigator, and the other as a marker. The amplitude of one signal is first monitored and the marker is moved vertically to a particular reference point on the trace. The investigative probe
is then moved to another signal source and the level here compared with the marked one. Further comparisons can be made at other strategic points.

CURRENT MEASURING

Current flow can be monitored using either one or two probes. By measuring the screen deflection both before and after a known value resistor, the peak difference is read and from it the peak current can be found by applying Ohm's Law. Conversely, if the current is already known, a resistance value may be equivalently calculated. Note though, that the impedance and inherent capacitance of the probe and its input amplifier will have an effect on the signal or voltage levels from a high impedance source.

TUNING

An oscilloscope of either single or dual trace variety is virtually indispensable in the tuning of filter circuits. It is so easy to observe the shape and amplitude of a filtered signal while carrying out adjustments to filter controls. Even for audio signals it beats listening for volume and distortion.

LISSAJOUS FIGURES

Practically every book I've ever seen on scopes talks about Lissajous figures. I've included the facility on this scope, though in fact I've rarely found the need to use them. Perhaps experienced readers may care to tell me how important they find the figures to be...

A Lissajous figure is created when two signals are individually applied to the X and Y deflection plates, and necessitates bypassing the time base generator. In this way patterns, such as those in Fig. 27 are displayed and from them phase or frequency differences between the signals can be established.

The classical use of a Lissajous figure is for frequency determination, usually, though not necessarily, using two sine waves. With a known frequency sinewave fed to one pair of deflection plates, the unknown sinewave is fed to the other pair. A series of loops is seen on the screen, and providing their ratios are within about ten-to-one, the nature of the pattern will be determined by the frequency relationship.

If the frequency ratios are precisely related harmonics, e.g. 2:1, 3:1, 1:4, 3:2 as in Fig. 27, the pattern will be stationary. Any shift away from the harmonic will result in the apparent rotation of the figure – moving pictures, folks!

The full interpretation of these figures can be complex and is beyond the scope of this article. Nonetheless, I'll give a few examples.

The frequency ratio can be found by counting the number of times that the pattern touches imaginary or real horizontal and vertical lines. In Fig. 27a, two peaks touch the X line, and one touches the Y line, the ratio is therefore 2:1. By similar reasoning, the pattern in Fig. 27d represents 3:2.

A further selection of ratio patterns is shown in Fig. 28, and as you can see, you don't necessarily need to have complete patterns displayed to find the ratio. If you examine the first display of Fig. 28 there is one loop on the X base, and two and a half loops on the Y side, converting to whole numbers the ratio is 2:5.

The figures don't always make such neat patterns and phase relationships will alter the pattern produced by the same frequency ratio. Fig. 29 shows three possible shapes for each of the ratios 2:1 and 3:2.

PHASING LISSAJOUS

The phase relationship between signals can be established by interpretation of the patterns produced for given ratios. Take a simple example of two sinewaves of identical frequency, produced perhaps by monitoring the input and output of an amplifier. If there is no phase shift a diagonal line from 225° to 45° will be seen, as in Fig. 30a. If the phase has changed by 180°, it has been inverted, the line will then be seen between 315° and 135°, Fig. 30b. Intermediate phase shifts will result in figures ranging from the diagonal lines, through ellipses to circles, the latter occurring when one signal lags the other by 90°, or precedes it by 270°.

Knowledge of precise phase changes will be largely academic to most people, so I won't go into detail about analysing the curves, but simply refer those interested to Fig. 31. Measurements of this type also require that the deflection amplitudes of the two signals are identical.

Ignoring mathematics, you can have a bit of fun (and probably impress a neighbour with your cleverness) with Lissajous figures by adjusting frequency inputs and waveforms to produce endlessly revolving patterns of different complexities. The figures are easier to control, and measure, when the frequencies are in the low audio range – higher rates are less easy to manage.

Fig. 30. Portraying phase relationships

SHAPING LISSAJOUS

Although the Lissajous technique can be used for waveforms of any shape, those with fast leading or trailing edges, such as sawteeth and squarewaves, tend to be difficult candidates. As a hint, though, you can sometimes make the pattern more observable for frequency matching by turning the brilliance fully up and defocusing, so spreading the beam more widely on the screen. Turning out the room lights can also help to make fast transients more visible in this and other scope modes!

To put this scope into Lissajous mode, switch S5 to position four. This opens the analogue gate to am Y1 only, and routes Y2 to VR3. Signals from the Y1 amp will continue to control the vertical trace, whereas Y2 will now control the horizontal trace. It will usually be preferable to switch S2 open and turn down the sync control.

Lissajous figures are also discussed by Ian Hickman in the Oscilloscopes book I referred to in part one. Another book, mentioned in Bookmark recently, also looks at them: Meters and Scopes (How to Use Test Equipment), by Robert J. Traister, published by Tab Books, ISBN 0-8306-2826-6.

Fig. 31. Measuring phase difference

Fig. 29. Variations in Lissajous patterns for the same frequency ratio
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SYNCING FEELINGS
It may seem that it is always desirable for a non-Lissajous waveform to be synchronised with the time base. This is true in many instances, for frequency assessment and shape comparison, for example. In other cases it’s more convenient if the trace is just a fast blur.

As an aside, when I was a film editor it was acceptable grammar for the verb ‘to synchronise’ to be extended to forms such as ‘sunk-up’, ‘unsunk’ and ‘sank’. I’ve even heard ‘sunk-up’, though ‘sunked-up’ was more common.

Neither sync nor optimum time base setting are needed for simple signal tracing, or dc level checking. In these instances seeing a vertical displacement of any sort is often enough to give answers about whether a signal is present or not, and as to whether a line is positive, negative or neutral.

SWEEPING UP THE TRACES
A scope is a vital piece of test gear for any electronics hobbiest, and in my own workshop it is used far more regularly than an ordinary meter. May you find as much benefit and pleasure from building and using this scope as I did when I built my first one. Once you’ve used a scope, however simple, you’ll reap the rewards from an enlightened view of how electronics works. So get the tube and beam yourself a board...

Suppose you are examining a high frequency signal, but wish to periodically compare its amplitude with that of a much lower frequency. When you need to look at the lower frequency the present high rate of the X sweep may be too fast for any of the slow waveform to be seen. You could switch down the time base rate accordingly, or simple turn the sync control fully down. Both waveforms will then be seen as a blur and amplitude differences readily compared. Even for measurements of individual waveforms this method can sometimes be easier than trying to see exactly where the waveform peak occurs.

Another use of non-sync viewing is when monitoring the swing of a very low frequency, of only fractions of a Hertz for example. Switch to a high time base rate, take off sync and the low frequency will be represented by a continuous line sweeping down the screen. This is an easier technique than switching to a synchronised low sweep rate when you will alternately be waiting for the start of the trace and then observing a solitary dot moving on the screen.

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Do you ever wonder if television viewing is influencing your life in any way? On the face of it the electronics industry seems to have produced a very powerful machine for changing our brain connections through the visual and auditory nerve pathways. Certainly it's the programme material that is responsible for arousing our emotions and thoughts. But the effectiveness with which this software does its job must depend a great deal on the current level of hardware technology.

This whole question is brought to mind by the prospect of increasing deregulation in UK broadcasting. A government White Paper due out at the time of writing will propose that the IBA should be abolished and all commercial television (terrestrial broadcasting, cable and satellite) be controlled by a new TV authority. Many broadcasting professionals fear this will mean lower programme standards, less real choice for viewers and a reduction in quality public service programming.

Clearly, television commercials do persuade people to go out and buy the goods or services advertised. Whether the portrayal of violence on television influences people to a similar extent to go out and commit violent acts is a matter for continuing debate. Probably a lot depends on the life experience of the individual viewer. For example, having become a rather cynical person, I make a point of never buying anything that is advertised on TV. But I have to admit that this selective, negative reaction is in itself an acknowledgement of the power of persuasion being applied.

A strong characteristic of domestic TV is its ability to exclude reality. To start with, consider how this works through the physical facts of the television set operating in the home. The images on the screen are produced by means of transmitted light from glowing phosphor sources, whereas we normally see most things in the world be reflected light. Sound is usually present most of the time, even though the real world often has to be interpreted in comparative silence.

The pictures are viewed in the humdrum surroundings of household objects and events. A furious bit of drama could be working itself out on the screen immediately next to a plate of sandwiches or a sleeping cat. On this screen the people and objects are miniatures, and the convergence feedback of our binocular vision tells us that the images are not the same as the originals seen at a distance. Overall the effect is something like a brightly lit toy theatre.

Within these physical limitations the deliberately selective processes of the broadcaster are operating. There is an old adage that newspapers can't tell you what to think but they do control what you think about. Selection and exclusion on television begin with the overall policy of the broadcaster. This is implemented first in programme planning and then in the structure and content of individual programmes. In political discussions, for example, the agenda is set in advance. Any controversy is held within previously determined limits, which can be enforced later by editing the video recording.

But it's in the 'language' and conventions of the visual presentation that we see exclusion and selection most immediately. First the sequence of shots is selected. Then each shot is structured by a variety of artifices - by choice duration, framing, lighting, the angle and distance from which it's taken, and so on. The precise meaning or mood which the viewer is expected to attach to the resulting images is fixed by the use of sound. Speech and music are very specific in their effects.

One result of this concentration of selective processes is a distancing or alienation of the viewer from normal experience. Jonathan Miller describes it well in a book on the one-time media guru, Marshall McLuhan. The images which television presents, he says, are "curiously dissociated from all other senses. The viewer sits watching them all in the drab comfort of his own home, cut off from the pain, heat and smell of what is actually going on. Even the sound is artificial." All these effects serve to distance the viewer from the scenes which he is watching, and eventually he falls into the unconscious belief that the events which happen on TV are going on in some unbelievably remote theatre of human activity. The alienating effect is magnified by the fact that the TV screen reduces all images to the same visual quality. Atrocity and entertainment alternate with one another on the same rectangle of bulging glass. Comedy and politics merge into one continuous ribbon of transmission.

Perhaps what Miller describes is the result of the most powerful selective process of all - in the mind of the viewer. If we seem to go into a kind of trance when watching TV it is because we have involuntarily agreed to suspend judgement on the reality of what is appearing on the screen. We have colluded with the TV producer in allowing ourselves to be transported by his art, shutting out our normal, hard-headed, sceptical sieves.

In this irrational state of suspended belief the contrived images and sounds become more 'real' to us than the real world. Temporarily we can be persuaded of anything. This metal state, and how to produce it, is well understood by television playwrights, propagandists and makers of commercials. The influence of the medium lies in the unperceived surrender of our minds.

One effect of continually excluding reality is to artificially raise the expectations of some people - particularly the deprived or unhappy - of what life should be like. Goodies are dangled in front of them. In the case of individuals who enjoy or need vigorous or violent action, certain TV programmes raise their levels of expectation of excitement from life. They have become addicted to their own adrenalin. When this excitement is not produced by the normal routine of living they go out and create it. This could be one contributory factor to the increasing violence in our society.
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Ed's quoted ten definitions for terms and names in regular electronic use, he's also given eight of the answers in a different order. Decide which answer goes with which definition and write it in the box. Two definitions are without quoted answers so into the relevant box just enter a name or term which you think is most appropriate.

The names of those with all the correct answers will be put into Ed's ex-Christmas hat on January 31st 1989 and the first three names drawn out will each win one of the three lcd tvs. The next three names drawn out will each win twelve month's free subscription to PE.

The winners will be announced in the April 1989 issue of PE, on sale from March 5th.

THE EDITOR'S DECISION IS FINAL!
Send the entry form to: Practical Electronics TV Competition, Intra House, 193 Uxbridge Road, London W12 9RA

EIGHT OF THE ANSWERS:
Battery, capacitance, chip, Farad, Henry, impedance, microprocessor, resistance.

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• The property exhibited by two conductors separated by a dielectric, whereby an electric charge becomes stored between the conductors.
• A multicell device which generates dc electricity by means of electro-chemical action and having a current supplying capability usually expressed in amp-hours.
• One or more elements that contain the control unit and logic functions suitable for use as the central processing unit of a microcomputer or dedicated automatic control system.
• The absolute SI unit of electrostatic capacitance, defined as that which, when charged by a potential difference of one volt, carries a charge of one coulomb.
• The absolute SI unit of self and mutual inductance of a closed circuit in which one volt is produced by a current changing uniformly at one amp per second.
• A small slab, wafer, or die of dielectric or semiconductor material on which a subminiature component or circuit is formed.
• In electrical and acoustical fields the real part of the impedance characterised by the dissipation of energy as opposed to its storage.
• The total opposition offered by a circuit or device to the flow of alternating current, the symbol for which is Z, and having the ohm as its unit.
• The science magazine for serious electronics and computer enthusiasts celebrating its silver jubilee in 1989.
• A leading British organisation committed to innovation, design, technology and reliability in audio, hifi, tv and video.

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