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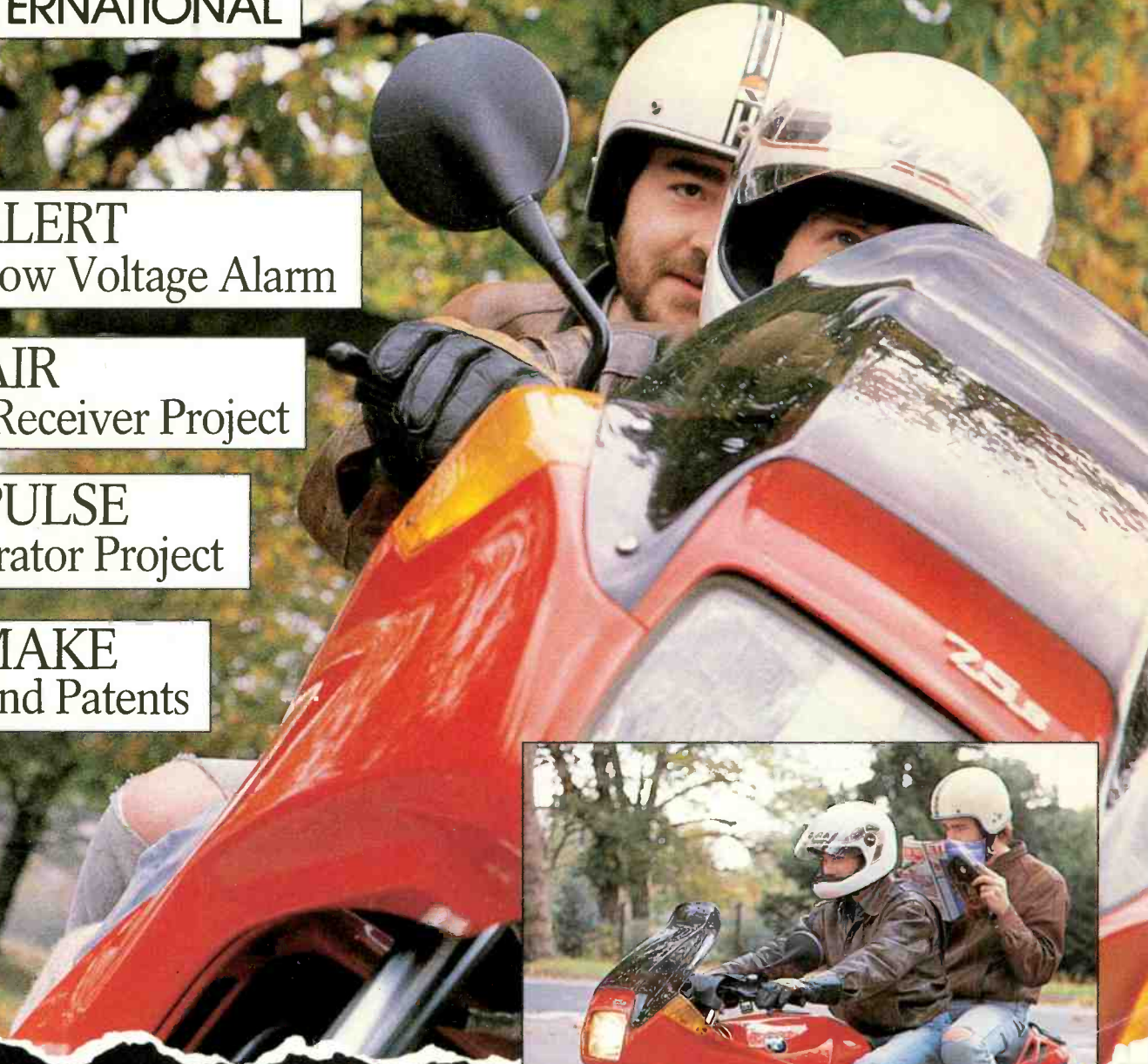
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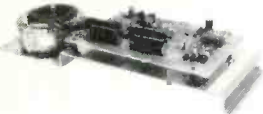
# POWER AMPLIFIER MODULES-TURNABLES-DIMMERS-LOUDSPEAKERS-19 INCH STEREO RACK AMPLIFIERS

## OMP POWER AMPLIFIER MODULES

Supplied ready built and tested.

**OMP POWER AMPLIFIER MODULES** Now enjoy a world-wide reputation for quality, reliability and performance at a realistic price. Four models available to suit the needs of the professional and hobby market, i.e., Industry, Leisure, Instrumental and Hi-Fi etc. When comparing prices, NOTE all models include Toroidal power supply, Integral heat sink, Glass fibre P.C.B., and Drive circuits to power compatible Vu meter. Open and short circuit proof.

### THOUSANDS OF MODULES PURCHASED BY PROFESSIONAL USERS



**OMP100 Mk 11 Bi-Polar** Output power 110 watts R.M.S. into 4 ohms, Frequency Response 15Hz - 30KHz - 3dB, T.H.D. 0.01%, S.N.R. -118dB, Sens. for Max. output 500mV at 10K, Size 355 x 115 x 65mm. PRICE £33.99 + £3.00 P&P.

### NEW SERIES II MOS-FET MODULES

**OMP/MF 100 Mos-Fet** Output power 110 watts R.M.S. into 4 ohms, Frequency Response 1Hz - 100KHz - 3dB, Damping Factor >300, Slew Rate 45V/uS, T.H.D. Typical 0.002%, Input Sensitivity 500mV, S.N.R. -125dB. Size 300 x 123 x 60mm. PRICE £39.99 + £3.00 P&P.

**OMP/MF200 Mos-Fet** Output power 200 watts R.M.S. into 4 ohms, Frequency Response 1Hz - 100KHz - 3dB, Damping Factor >300, Slew Rate 50V/uS, T.H.D. Typical 0.001%, Input Sensitivity 500mV, S.N.R. -130dB. Size 300 x 155 x 100mm. PRICE £62.99 + £3.50 P&P.

**OMP/MF300 Mos-Fet** Output power 300 watts R.M.S. into 4 ohms, Frequency Response 1Hz - 100KHz - 3dB, Damping Factor >300, Slew Rate 60V/uS, T.H.D. Typical 0.0008%, Input Sensitivity 500mV, S.N.R. -130dB. Size 330 x 175 x 100mm. PRICE £79.99 + £4.50 P&P.

NOTE:- MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS. STANDARD - INPUT SENS. 500mV BAND WIDTH 100KHz PEC (PROFESSIONAL EQUIPMENT COMPATIBLE) - INPUT SENS. 775mV, BAND WIDTH 50KHz. ORDER STANDARD OR PEC



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- 10" 200 WATT C10200GP GUITAR, KEYBOARD, DISCO. EXCELLENT HIGH POWER MID RES, FREQ. 45Hz, FREQ. RESP. TO 7KHz, SENS. 103dB. PRICE £48.67 + £2.50 P&P
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- 12" 100 WATT C12100TC TWIN CONE) HIGH POWER WIDE RESPONSE, P.A., VOICE, DISCO. RES, FREQ. 45Hz, FREQ. RESP. TO 14KHz, SENS. 100dB. PRICE £38.58 + £3.50 P&P
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- 10" 50 WATT EB10-50 DUAL IMPEDANCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR. RES, FREQ. 40Hz, FREQ. RESP. TO 5KHz, SENS. 99dB. PRICE £12.00 + £2.50 P&P
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- 12" 60 WATT EB12-60 BASS, HI-FI, STUDIO. RES, FREQ. 28Hz, FREQ. RESP. TO 3KHz, SENS. 92dB. PRICE £21.00 + £3.00 P&P
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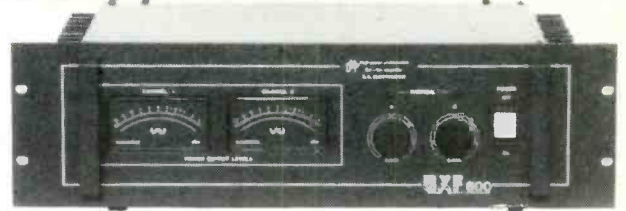
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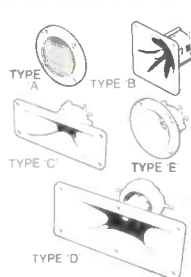
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SECURICOR DEL:- £12.00 PER PAIR

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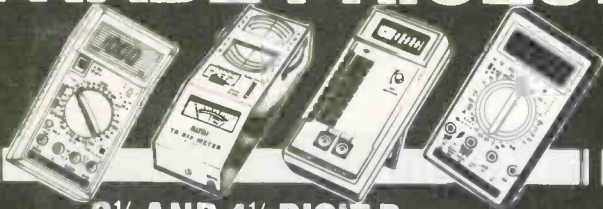
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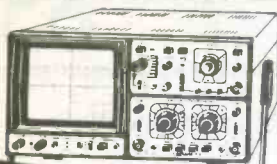
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Page 18



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## REGULARS

### News

6

### Subscriptions

8

### Blueprint

9

### Open Channel

10

### Penta Show Report

11

### Keynotes Column

The Omnichord 200M — a musical instrument with a difference. Chris Jenkins strums the strings

12



### Insight — Living On Mercury

13

### Out On The Streets

13

### Competition Results

33

### PCB Service

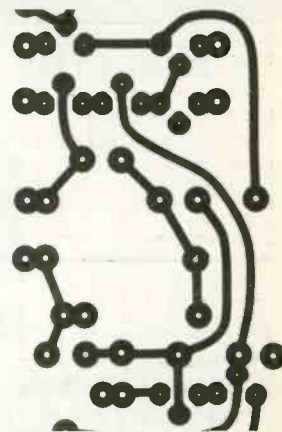
35

### Newsagents

60

### Oooooops!

61



### PCB Foil Patterns

61

### Classified Ads

63

### Special Offer

65

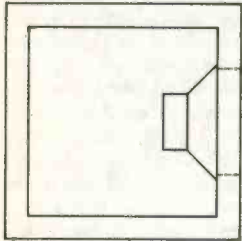
### Next Month

66

### Ad Index

66

## FEATURES/PROJECTS



### The Infinite Baffle

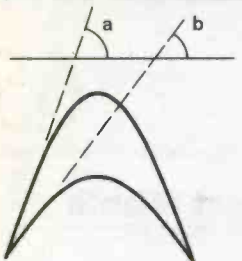
Jeff Macauley takes the baffling bits from the art of infinite baffle loudspeakers and presents a case of good design

14

### Patents and the Art of Invention

Pat Alley thinks it's patently obvious that inventions should be protected. He writes copy on copyright and the minefield of patent application

18



### Testing Testing

Mike Barwise continues his journey through the instrumentation environment, stopping this month to monitor real-time and display recorders

24

### CIRCUITS

#### Tech Tips

A selection of circuits supplied to us by the ingenious readers of ETI

- Radio transmitter alarm
- Battery charger
- Bicycle light control
- Touch-activated light switch

29

#### ETI Index part 2

A complete list of all the features and circuits from the last twelve months of ETI

34

### PROJECT

#### Motorcycle Intercom

The word is on the streets — in the form of Tim Oxtoby's rider-passenger 2-way logic-switched voice-activated heavily-hyphenated intercom.

36

### PROJECT

#### Wavemaker FG

A function generator for those who need effective equipment on an easy outlay. Dominic Banham has his soldering iron on the pulse

42

### PROJECT

#### Low Voltage Alarm

Keith Brindley can spot a slipping potential without a probe or a prod. This beginners' project shows how.

46

### PROJECT

#### Under Surveillance

5: Mini Bug Circuits  
The free PCB on this month's cover is put to work to make two room bugs, a telephone bug and a cordless guitar pick-up. Paul Chappell squeezes them in

48



### PROJECT

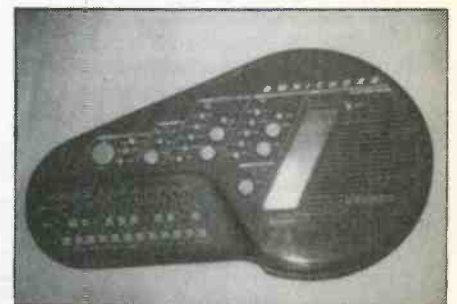
#### 20m Radio Receiver

David Silvester twiddles his direct conversion receiver into the amateur band

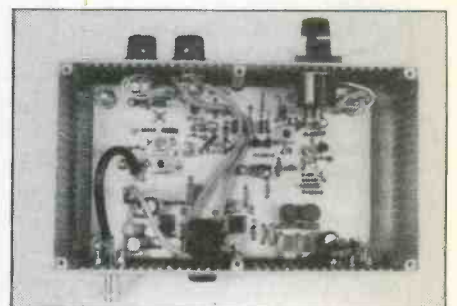
54



Page 36



Page 12



Page 54



Page 42

# NEWS

## THE HEAT IS ON

**D**ire warnings about the change in global ecology causing unthinkable catastrophes has begun to prompt thinking into ways of reducing man's excessive production of polluting substances. After all, the key to the 'green' revolution is to use less energy. Two important aspects arise from this — consume less or become energy efficient. Thoughts behind energy efficiency are now stronger than ever before. However, although the latest applied technology in this field has had the best intentions, it may just backfire through lack of in-depth knowledge about our style of living.

Two cases in point.

A hospital, interested in reducing wasted heat energy by better temperature control of buildings, installed an electronic heating management system. Automatic control came from computer, telephone line and sensors placed throughout the building.

Such were the frustrations of the staff in not being able to obtain the warmth at the correct time that it didn't take long for 'nurse' control to override the system. They realised that by placing hot water bottles or ice packs on the wallplate sensors, they could supply their own heating needs more immediately.

The second case concerns a large school building that had similar electronic controlled treatment imposed upon it from County Hall, a building some 40 miles away.

It quickly became apparent that the degree of control was insufficient for the size of the building. The system produced large thermal delays and temperature differences throughout the building. So the central regions became too hot and people opened windows in winter, whilst staff on the extremities couldn't cope with frozen conditions, and to resume their activities imported butane gas heaters.

No doubt problems like these can be sorted out, but it does show the need to study all factors when short sighted ideas for better energy management ironically produce a greater usage of energy rather than less.

*If anybody out there has an effective electronic energy management project that they have designed, ETI would like to hear about it.*

Backnumber readers should note that the ETI-DCP special offer of Interspecs has now sold out. The Interbeeps are still available as are the special offers featured in this issue. The I-Tron sound effects special offer has also now closed

## BASS VALUE



**Q**uality continues to improve and prices to fall in the personal stereo market.

The latest stereo cassette player from Panasonic (RQ-P155) features its XBS (extra bass) system, Dolby B noise reduction, a three band graphic equaliser and metal tape capability.

Lack of bass from personal headphones has caused Panasonic to create a circuit that provides extra bass to compensate for this loss. This switchable control is equivalent to the loudness control on a hi-fi system.

Its small size (114 x 85 x 37mm) makes it convenient to fit in an inside pocket, but the shape and size of the headphones still leaves you wondering where they can be easily stored. The RQ-P155 retails at ££4.95 and is available now.

## HANDY CAP



**I**f measuring capacitance has been a problem for you, then the GMD1.1 from Global hand held multimeter could be your answer.

The 3 1/2-digit liquid crystal display will measure up to 20µ in five ranges of capacitance. The multimeter also provides six ranges of resistance, voltage up to 1000V DC and 750V AC and apart from the measurement of µp to 200mA AC/DC, a high current 10A range of current is also available. Probes are also included in the purchase price of £49.95. Contact Global Specialties on (0234) 217856 for further information.

## MELTDOWN

**U**oSAT-1 — the first in a series of small low cost satellites built by the University of Surrey — has suffered a fiery death. After eight years operational in orbit, the satellite entered the Earth's atmosphere and vaporised.

Built by researchers at the University for approximately £250,000 and launched free of charge by NASA in October 1981, UoSAT-1 has long outlived its original design lifetime of three years. The satellite has far exceeded the expectations of the researchers at Surrey.

NASA launched UoSAT-1 — a 60kg 'microsatellite' — into a 500km orbit on 6 October 1981 from the Vandenberg Air Base in California, as a piggy-back secondary payload on a DELTA rocket which had the 500kg Solar Mesosphere Explorer satellite as its primary passenger. Research engineers at the University of Surrey designed UoSAT-1 to demonstrate the use of small inexpensive microsatellites for space research, in-orbit technology demonstration and space education. UoSAT-1 has achieved these objectives through numerous onboard experiments, including Geiger radiation detectors and a computer-controlled speech synthesiser.

Over 3000 school children, university students and radio amateurs from more than 40 countries have

participated directly in the mission by receiving data directly from UoSAT-1 on small, inexpensive radio receivers and displaying the results on personal microcomputers. Surrey researchers' experiments with UoSAT-1 in orbit have sparked a new interest within ESA, NASA and the space industry in inexpensive yet sophisticated microsatellites.

Air-drag from the tiny amount of residual atmosphere at 550 km has caused UoSAT-1 to fall slowly towards Earth, causing its demise. The current peak in activity of the 11-year sunspot cycle has caused the Earth's atmosphere to expand and dramatically increase the air-drag on the small satellite — which was travelling at about 18,000mph. As a satellite falls towards Earth, the density of the air increases — further increasing air-drag and the rate of descent. The end therefore, came quite rapidly; UoSAT-1 dropped at about 1 km each day and burned up during October — around its eighth birthday! Travelling at such a high speed, the frictional heat generated by air-drag caused the satellite to vaporise completely when reaching the denser regions of the upper atmosphere.

The University is the leading academic institution in spacecraft engineering research and teaching in Europe, and is recognised even in the USA as the leading pioneer in the field.

## MIXING WITH MAPLIN



**M**aplin Electronics now has a six channel 'professional' mixing desk to offer its customers.

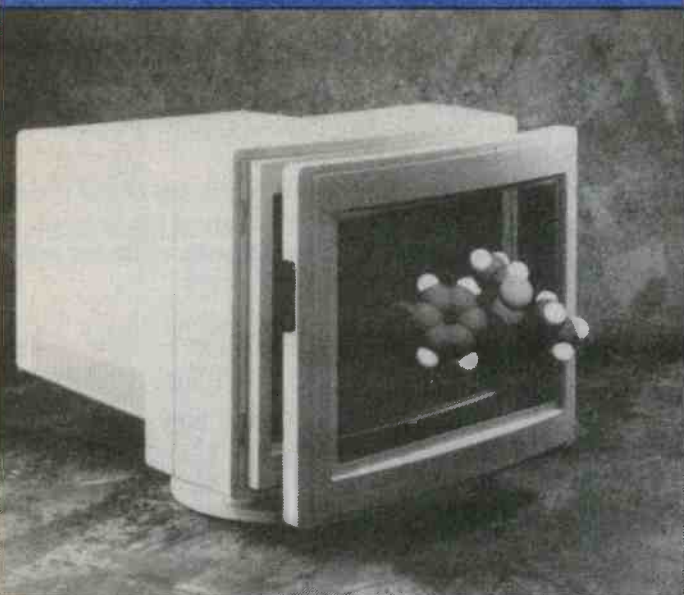
The desk comes with a seven channel graphic equaliser and each mixing channel will control treble, bass, pan, cue, effect, preset level and master gain. When it comes to monitoring line levels, two VUs are provided at the mix out and each

channel provides an LED to warn of over modulation. A controllable headphone jack delivers the stereo output from either line out or from the cue facility.

The mixer retails at a non-professional price of £279.95 including VAT.

Further information from Maplin on (0702) 552911.

## POLARISED 3D RTGB TV



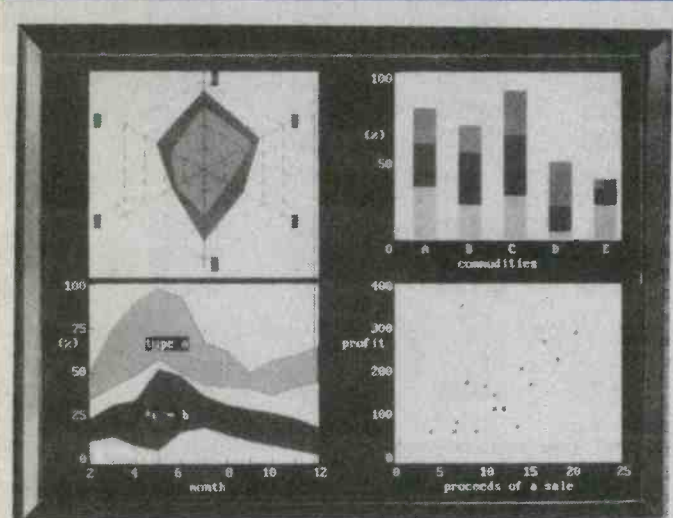
**A** new 3D stereoscopic monitor is now available from Tektronix. The 10in high-resolution screen is a Trinitron RGB colour monitor with a detachable liquid crystal stereoscopic modulator.

Producing a three dimensional image on screen requires two cameras, placed at eye distance apart, to return the signals to the monitor. The signals are then rapidly alternated on screen. The modulator mask

separates the two images by circular polarisation for each eye.

To see the image, viewers wear a pair of passive glasses containing circularly polarised lenses. One of the advantages of this system is that many people can see the images at one time. They can enjoy flicker-free full colour pictures and the object can be observed at a greater angle than any other monitors could give previously.

## THIN FILMS ON TV



### 640 x 480 10" Colour TFT LCD

**H**itachi has been previewing its latest liquid crystal display. The new 10in colour display will be in full production in 1991. The active 640x480 pixel matrix panel is designed to work in workstations and VDU terminals that require high resolution colour displays. The screen employs thin film transistor technology with integral colour filters to produce a high

contrast, wide viewing and fast display writing capability. Three primary coloured adjacent dots produce a total of eight colours including black and white.

It contains built in video data conversion circuitry to handle CRT compatible signals, which means that these displays could mark the beginning of the end for conventional monitors.

## MINI MOUSE

**J**oysticks, trackballs and mice have all had their part to play in the ease of relaying information from point to point within the computer, but wherever motion occurs with these instruments, space is required. This could be a problem especially if you are an executive on a flight manipulating a mouse or trackball with a lap-top computer.

Now an inventor has come up with a possible solution — a motionless mouse. It's a case where your fingers do the walking or moving.

About the size of a pocket diary, the sealed box requires a slight rocking of the finger to facilitate cursor movement. The surface is touch sensitive and so any lifting of the finger causes a reduction in sensitivity and

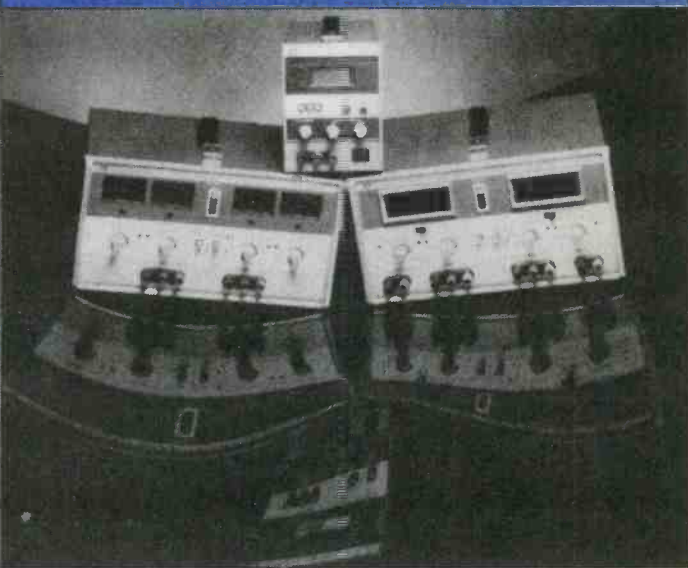
a second finger can adjust the cursor to the nearest pixel. One sensor performs the action of four switches which includes changing sensitivity and emulating the switches on a mouse control. The right sensor is responsible for cursor movement on screen.

This latest design is expected to be of value in flight simulation at one end of the spectrum to games programs at the other — situations where an extreme degree of alertness is required.

Three versions of the Magic Touchpad will be available they are joystick, quadrature and mouse emulators.

Further information contact Culton on (0306) 885138.

## TAKING FLIGHT



**I**f you are stuck for a bench power supply, then perhaps Flight Electronics could meet your needs.

The range offers reliability and a wide choice of single, double and quadruple variable output units. The units can provide three and a half digit LCD/LED displays or the traditional analogue meters.

A single output model can supply 0-18V (0-20A), 0-30V (0-10A) and 0-60V (0-30A). This supply, with analogue meters costs £89.00 whilst the digital display will set you back £148.00.

Further information telephone Flight on (0703) 227721.

## PICTURE THIS

**J**apanese camera manufacturers continue to develop the 'electronic film', a memory chip that stores the visual image.

The latest still cameras out for Christmas in Tokyo will store the picture digitally on a credit card sized piece of plastic.

Toshiba and Fuji Film have jointly developed the camera system incorporating the card. It can contain 12 photo images, stored digitally within 18 one megabit chips in the plastic. Picture quality is said to be the most

critical factor and in this case, picture resolution comes from a horizontal scan of 400 lines per frame.

The flexibility of storing a picture electronically means that up to 1000 pictures can be held on a 120 minute video cassette and displayed to all your friends via TV.

This latest technology can be combined with larger memory capacity to give computers the ability to hold not only text and data, but also picture information for documents and profiles.

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Radio Modeller	£16.80	£22.40	£22.60	£24.80	£23.00
Renovate	£18.00	£22.80	£23.00	£24.80	£23.30
Scale Models International	£18.00	£21.45	£21.60	£23.35	£21.90
Video Today	£18.00	£23.20	£23.40	£25.35	£23.70
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# BLUEPRINT

Blueprint is a column intended to provide suggested answers to readers' electronics design problems. Designs are only carried out for items to be published, and will not be prototyped by the columnist. Circuits published in Blueprint are believed to work, but may need minor alteration by the reader after prototyping. Individual correspondence will not be entered into, save as necessary to prepare items for publication.

This month we have a question from Karen Newall, a student teacher of design and technology, who intends to produce a timer for use by the blind as her third year project. She has some ideas about how to proceed, but insufficient knowledge of electronics to make the whole thing work.

The purpose of the timer is to permit a blind person to set a tape recorder to record a radio programme while he/she is out. This is easily done by someone who can see, using a plug-in digital timeswitch costing under £20, but this is no use if you can't read the display. There are many ways to tackle this sort of problem, but most of them can be ruled out by the circumstances in which it is being designed. For example, a product designed for mass production could work like ordinary digital timers, but replace the digital readout with a speech synthesizer. To make it small enough, one would probably use surface mount ICs, perhaps holding the data on a windowless EPROM. There's unlikely to be enough market to justify mask programming, though market research would confirm or deny this.

It would be possible to check each digit of a readout by having a button under each digit which would cause the equipment to emit a series of coded beeps — perhaps sending each digit in morse. The setting process would be difficult and there would be the temptation not to check the setting always.

Any solutions involving even more fancy technology, perhaps with custom chips, would be too ambitious for the intended project so I suggested that a simple interval timer should be used, with one row of rotary switches setting the time delay before it switches on, and a second row setting the on time. The switches could be arranged to have pointer knobs to indicate the setting by touch. This could be double checked from time to time by counting clicks from the stop.

This would of course, only allow the setting of one time period during the day. However, it would be easy to set and could be designed using standard components. The complexity of this type of circuit would not be so great that prototypes should be seriously unreliable.

## Timing

The implication of the question is that the circuit should operate on the mains, and should switch a mains load. If this is the case, then the mains frequency should be used for timing purposes. If the load to be switched is only low-current, then a triac can be used to switch it. Because of the prototype nature of any project to be produced, it would probably be advis-

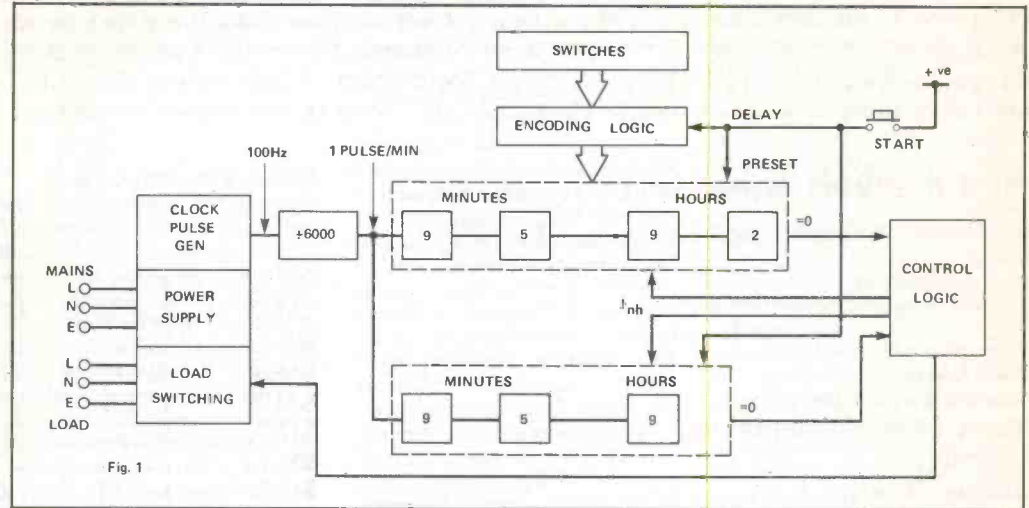


Fig. 1

able to use opto-isolated triac drivers and a miniature mains transformer to power the circuit in order to isolate all the electronics from the mains. If this were to be developed into a mass-produced item and properly production engineered, it would be possible to incorporate suitable double insulation to render the unit safe without opto-isolation, and with the power supply drawn from a dropper resistor from the mains. This, however, would be a second step after the basic development had been carried out.

The actual timing of the clock pulses derived from the mains can be done using ordinary CMOS counter/divider ICs. The obvious method would be to use one set of counters and use binary comparators to determine the switch on and off times. However, a little thought shows that a slightly simpler solution is to use down counters, clocked (say) once per minute, and connected to switch the output when they reach zero. This reasoning gives rise to the block diagram shown in Fig. 1.

Starting with the switches, if one were to stick with the maximum 24 hour time period, only one of the

switches would need as many as ten positions, though it may be convenient to extend the time delay to 29 hours 59 minutes. It would seem reasonable to limit the ON period to 9 hours 59 minutes, since periods of over 1½ hours are not likely to be required very often.

It would be useful if BCD switches were available, but all the BCD switches found so far would not be suitable for setting by a blind person. The switches fall into two main categories: PCB-mounting presets adjusted by a screwdriver, or thumbwheels switches, generally with the numerical indication behind a window. Unless a suitable switch can be found, it would seem necessary to use good old fashioned ten-way rotary selector switches. The output from these switches can be turned into binary-coded-decimal either by the use of a standard CMOS chip for the job, or in the case of switches not covering the full range of 0 to 9, it may be simpler and cheaper to use CMOS random logic. Whatever the detail of it, encoding logic is needed between the switches and the counters.

The counters themselves need to

be parallel loadable down counters, capable of being cascaded and having an output indicating that they have reached zero count. The 4029 in its downcount mode meets this requirement, and is the obvious choice.

Each digit of the counters can use a similarly connected 4029. The different count number for each stage is determined in the programming logic. Fig. 2 shows an example of the method of connection. Just two stages are cascaded here, but this can be extended as far as necessary. The gate and flip-flop around each 4029 are to permit the counter to count round to reload its maximum number and start counting down again when it reaches terminal count. It must not reset to start immediately that it reaches zero because TC must be held low for long enough to allow the next counter to count. The flip-flop causes the 4029 to reset on the positive clock edge after the one which sets the TC output to 0. The OR gate permits the counters to be set regardless of the state of the clock waveform.

Next month Blueprint will cover the rest of the logic.

Andrew Armstrong

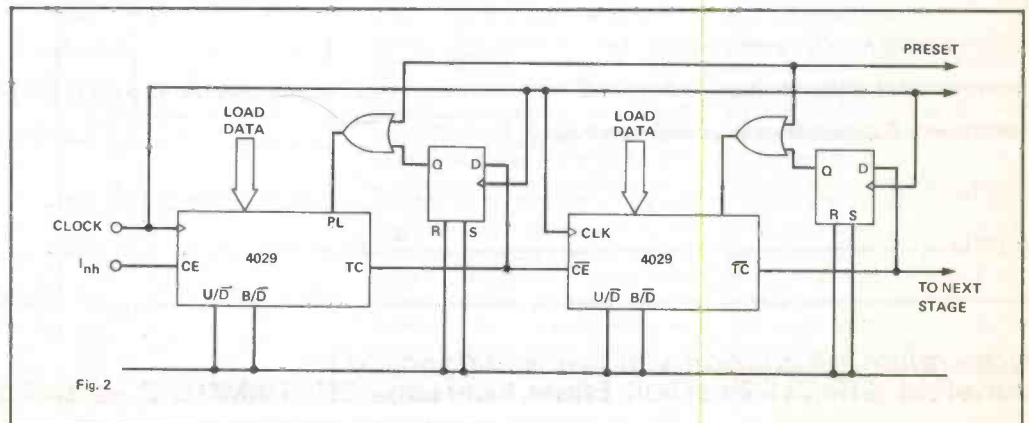
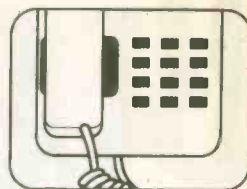


Fig. 2

# OPEN CHANNEL



The International Telegraph and Telephone Consultative Committee (CCITT) has recently put forward comprehensive plans for a world telecommunications network of the future. CCITT study group XI, which is responsible for standards relating to integrated services digital networks (ISDNs) and all telephone network switching and signalling systems, has proposed worldwide standardisation of networks in digital form.

The problem with existing plans for ISDNs throughout the world is that they are being developed divergently, some not being compatible with mainstream telecomms technology. The new concept of a network, which can really be thought of in terms of a convergence of all current ideas on future networks, is called the intelligent network (IN). Apart from other innovative ideas, it will comprise many databases spread across the public communications network, so that rapid and inexpensive installation of a wide variety of old and new services can be offered.

One of the important points to come out of the CCITT plans is that no distinction is to be made between public and private networks. Further, private users are to be allowed to participate in the making of the required standards.

An overall IN will encourage telecomms liberalisation here and abroad simply because of the fact that users and private network suppliers will have immediate and equal access to public network resources.

A fairly ambitious timetable has been proposed by the CCITT, requiring that firm standards are produced by the end of 1991 — which doesn't give a lot of time.

## What's In Store For EPOS

Electronic point of sale (EPOS) equipment — high-technology equipment in retail outlets designed to ease the job of selling and paying for goods — has only just recently invaded the high-street. My local Sainsbury's, for example, has laser bar-code reading equipment at each checkout where the operator merely moves each item across the reader's surface and the product code is automatically determined. I can pay for the goods, if I wish, by *Switch* card. The operator merely wipes my card through a magnetic striped card reader, the till rapidly prints out a sales voucher which I sign, Sainsbury's computer contacts my bank's computer and my bank account is debited by the sales account. Similar card readers are available for credit cards too (not at Sainsbury's), usually found at petrol stations and the like.

Although this technology appears to be the norm these days, it's interesting to find out that only 15% of sale points currently have EPOS technology of any description. This situation is rapidly changing and has been forecast to double next year.

New and innovative EPOS equipment looks set to feature in the near future. One example is the electronic shelf edge display (I suppose we could acronymise this to ESED, although I've never seen it done yet) which is reckoned to have the biggest potential of all new EPOS equipment. In this, electronic displays mounted on the edge of display shelves in supermarkets will automatically display information such as goods prices, weights, contents and so on. A central computer transmits display information to the displays, so that changing a product's price or other information, simply becomes a matter of typing it in at the keyboard. For the retailer, the advantages include staff reduction and great flexibility in display positioning. For the consumer on the other hand, advantages include the possibility of actually being able to find how much the product costs for once (if you're a regular supermarket shopper, you'll know how frustrating it is when you find unpriced goods you want to know the cost of!).

Many systems are in development as you'd expect, using many telecommunications methods to transmit the necessary information from computer to shelf edge display. Cable, fibre optics, infra-red beams are all going to be common in the years ahead. But one system which deserves note for its cleverness will use a radio signal to transmit data. The obvious advantage which such a system gives over all the other methods is ease of installation — no need for cable routing and the messy installation work which goes with it!

Ah ha, I hear you say! But what about the necessary radio licence to operate the system. Well, that's where the system is doubly clever — a licence is not required. This is because a loop aerial is used (a simple loop of wire), attached to the ceiling of the outlet, to transmit longwave radio signals. And because the required transmissions are then so weak, they are contained totally within the building, the system neatly sidesteps any licence requirements. Interestingly, the idea is not new. If my memory serves me correctly, it was first used in the world's first radio-paging system around thirty years ago in a London hospital (here my memory doesn't serve me because I can't remember the hospital's name), to enable doctors to be 'bleeped' in much the same way they are still being 'bleeped' nowadays when emergencies occur. Loop

aerials haven't been used in radio-paging systems, though, for many a year. Curiously nostalgic to see them being used again for such a high-tech venture.

## Mobile Personal Cones

Watching the hoo-hah which has been going on over mobile personal communications such as CT2 and PCN, I get the feeling that there's something up we ought to be aware of. CT2 is of course the cryptic name given to second generation cordless telephones of the telepoint ilk, while PCNs are the new personal communications networks proposed by the DTI to come somewhere between CT2 and cellular telephone systems. Look to November's ETI, where I compare and contrast all three, if you're in any doubt about what each is capable of.

Our Government's idea in forging ahead with these systems has obviously been to open the market out for British companies to compete with the advantage that they have had more experience than foreign ones.

What has happened is that many European companies have simply ignored the British push for these networks. As far as CT2 is concerned, there is a large and growing European contingent against our adopted standard, instead opting for the more advanced digital European cordless telephone (DECT) standard. With PCNs, it looks as though most European companies are simply not con-

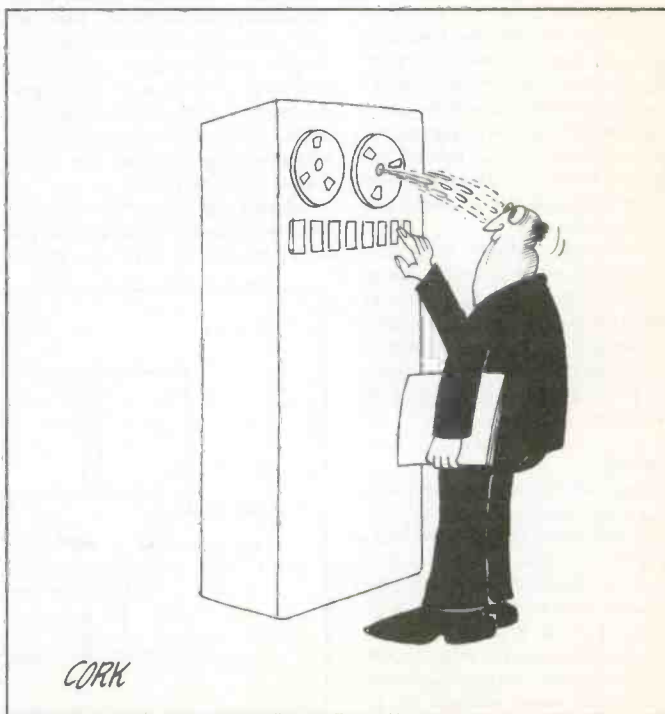
sidering their value at all — it was interesting to note that none of the large European mobile communications manufacturers even bothered to apply to the DTI for an operating licence.

There are two ways of looking at this. The first, which I've seen proposed by other commentators, is the rest of Europe is using Britain as a sort of free evaluation service, to exploit while making sure their own markets are not damaged. Thus, we go ahead with things like CT2 and PCNs, generating a lot of work for our own companies, and when things are proven — or more specifically, disproven — they go ahead with optical systems, leaving ours in the doldrums.

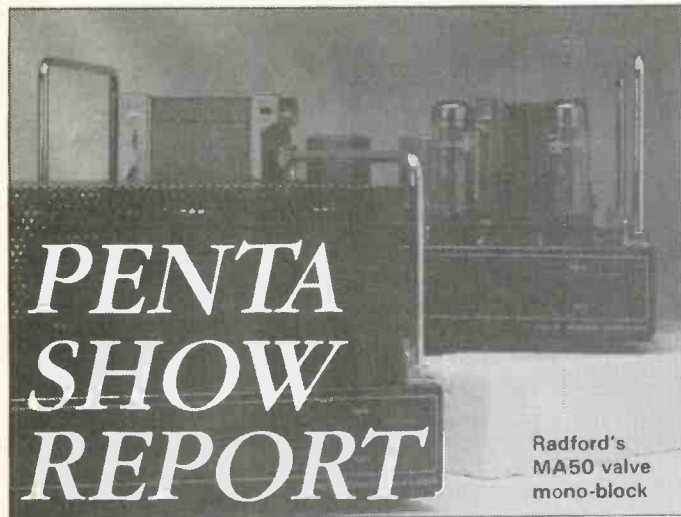
This scenario I find a little disturbing, and I don't subscribe to it. I just can't believe that Europe's leading telecommunications companies would use such devious and underhand methods of gaining an edge over ours. It all smacks too much of Big Brother and I don't believe that such an organised situation could arise, simply to undermine British companies.

I prefer a second way of looking at the situation. In this, I propose that the fault is our own, or at least our Government's. In the haste to try to give our companies the European market edge, our telecomms liberalisation procedures have simply been pushed ahead too quickly. Now, our companies are out on a limb — and the limb looks as though it could break.

Keith Brindley



# PENTA



## PENTA SHOW REPORT

Radford's MA50 valve mono-block

If you are serious about designing top quality hi-fi electronics, you will need to be good at designing valve circuits.

That seems to be the message which flows most strongly from Britain's largest exhibition of hi-fi equipment held each year at the Heathrow Penta hotel in West London. Not only were there quite a number of manufacturers and suppliers of valve-based electronics, but also many manufacturers of turntables and loudspeakers who preferred to demonstrate the sonic virtues of their designs using valve amplification. On top of that, the only supplier of electronic components exhibiting was valve specialist supplier PM Components. Certainly the overall impression was that the importance of valves in hi-fi equipment overshadowed the technical advances in digital engineering.

Moving into the digital field, the most interesting exhibit was the Wadia Digital-2000 decoding computer which offered 64x oversampling in converting digital signals to analogue. The advantages, one learns after filtering the relevant information from their brochure, are that noise generated in between the steps is well above 2MHz and hence beyond the operating frequency of audio amplifiers and that the digital filter which causes distortion in real music signals is eliminated. Their second model the Digital-1000 offers 16x oversampling, on a par with the new Cambridge Audio CD3.

One pertinent observation is that CD technology is becoming accepted amongst the leading analogue engineers who have used their knowledge and experience to improve it. Woodside Electronics, famous for remanufacturing the old Radford Valve amplifiers of times past, has introduced its own WS1 compact disc player at just under £1000 and the PAC1 digital-to-analogue converter at just under £500. Another leading

analogue specialist is Deltic Precision Audio whose amplifiers are based around its high performance 500MHz hybrid op-amp microcircuit. Its CD converter, again at just under £500, is based on Pulse Density Modulation. It eliminates the problems of matching resistors and from this technology low level performance is theoretically superior. One might well wonder how much more successful the launch of CD might have been designed by competent analogue engineers.

Digital Audio Tape recorders are making more waves on the legal and political front than on the musical or electronic fronts, but I did see one DAT recorder, the R-1 exhibited by Teac.

Still on digital engineering Meridan Audio's new D600 loudspeaker includes a remote controlled preamp capable of accepting digital or line level analogue input signals, electronic crossover and three power amplifiers directly driving the three drive units. These are designed for the 'Total system' concept of providing hi-fi sound in several rooms of a house from a master control system. This is moving away from the concept of hi-fi as a 'Rack system plus two boxes' at one end of the room.

Also on the same tack was KEF with its in-wall loudspeakers. The loudspeakers are mounted on a baffleboard which fits into a recess in the wall less than four inches deep. Because of the excellent baffle provided by the wall a low frequency subwoofer is included in the range, and this extends down to 32Hz. It would be useful addition to most standard hi-fi systems.

Surround sound was demonstrated by Dynavector with its SSA504 4-channel amplifier. By using three separate delay lines, the first of which is fed to the front channels, Dynavector claims to provide a more convincing and realistic experience of a concert hall.

Graham Nalty

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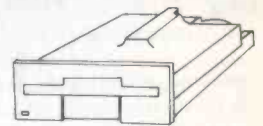
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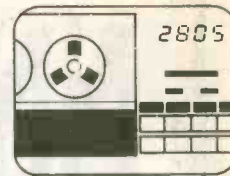
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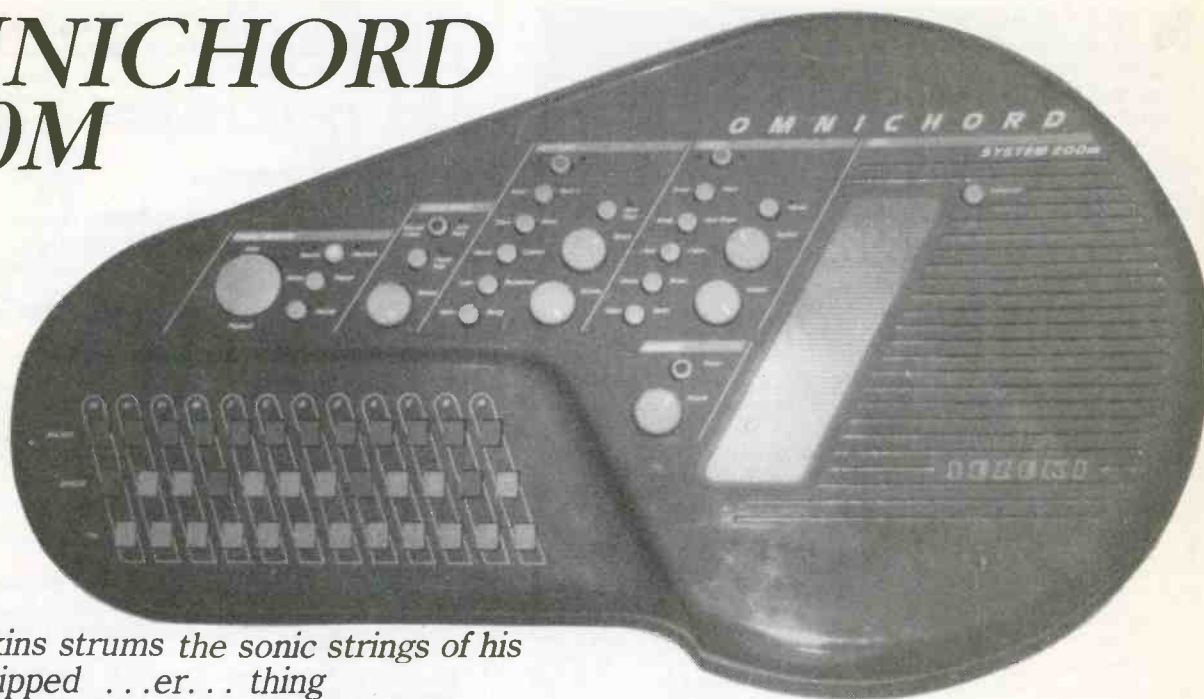
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# KEYNOTES



## OMNICHORD 200M



*Chris Jenkins strums the sonic strings of his MIDI-equipped . . .er. . . thing*

**Product:** Suzuki Omnichord 200M

**Price:** £250

**Supplier:** KES Music Services, 26 Elms Road, Harrow and Wealdstone, Middlesex HA3 6BQ

**Tel:** 01-954 8176

The Omnichord is a unique musical device, proving that while MIDI is usually associated with keyboard instruments, the same communication standard can apply equally well to different forms of controllers. After all, a keyboard is basically just a series of switches, and any digital system which can provide the right input can be used to generate MIDI.

Alternative controllers like MIDI guitars, percussion pads and wind instruments are now well established, but some designers are looking at completely new types of controller — Jean-Michel Jarre's famous Laser Harp and EMS's Soundbeam for instance. The closest acoustic equivalent of the Omnichord is the autoharp, which lets you strum strings while selecting the key with a series of buttons. As we'll see, however, the Omnichord has also inherited a fair amount from the idea of the home organ.

### History

The Suzuki Omnichord first appeared a couple of years ago, and has sold well into the educational, leisure and domestic markets. Several variations on the original non MIDI version are still available, but it's taken a surprisingly long time for the designers to take the obvious step of adding

MIDI. A prototype was shown at the British Music Fair in June, and the MIDI Omnichord 200M should be available in time for Christmas.

The great thing about the Omnichord is that it allows non-musicians to create enjoyable music and, via MIDI, to use all the facilities of modern synthesizers and other instruments.

The oddly-shaped Omnichord can be played sat on your lap or slung round your neck. Powered by batteries or a 12V mains adaptor, it has a small built-in speaker but obviously benefits from amplification via its quarter-inch jack audio output socket.

The basic idea is simple. Like a home organ, the Omnichord has a series of single-finger chord buttons, a rhythm unit and automatic bass patterns. Instead of a keyboard, there's a touch-sensitive *sonic strings* strip. Running your fingertip over this strip produces a four-octave glissando of notes in the correct chord — in other words, it's impossible to play a wrong note!

### Features

The 36 chord buttons are arranged in three strips; majors, minors and sevenths. By pressing them in combination you can produce 84 different chords. When you switch the Omnichord 200M on, it defaults to *sync start* mode; press a chord button and the chords, bass and drum machine start playing at the speed set by the Tempo knob. The chord sound is a simple organ texture, the bass a little better, but the drum sounds are fairly punchy PCM samples.

There are ten different rhythms, selected with a row of pressbuttons, ranging from rock to disco, march, waltz, bossanova and so on. It would be nice to have a larger selection, or more fills or variations, but no such luck. However, there are different chord and bass patterns matching the different rhythms.

The *sonic strings* sounds are better. There are ten, including guitar, synth, bell and flute. You can alter the sustain time and add a tremolo effect for more variation, and each section has its own volume balance control.

Once you've experimented with different styles of playing the Omnichord — strumming, tapping, or pressing the Sonic Strings — you can get into the more complex functions. In the *chord memory* section you can activate *record*, then use the chord buttons and *enter* key to create a sequence of up to 51 chords, pressing *delete* if you make a mistake. Go into *playback* mode and you can play the chords back in sequence just by tapping the *playback* pad, or using an optional footswitch.

The *Chord Memory* can be partitioned into four sections, and these songs selected using dual-function chord buttons. For a live performance you could store up to four short songs and not even have to remember what chord buttons to press.

By selecting the *melody* feature you can actually pick out specific notes on a one-and-a-half-octave 'keyboard' laid out among the chord buttons, rather than strumming the Sonic Strings.

### MIDI

All this is ideal for, say, singers who want accompaniment but can't play a conventional keyboard or guitar. However the really fascinating applications arise when you start using the Omnichord 200M's MIDI facilities.

The MIDI implementation is pretty basic: Melody notes are transmitted on channel 1, bass on 2, chords on 3, drums do nowt. Obviously there's no MIDI velocity transmitted, which is understandable, but it would have been nice to see MIDI patch change control or timing clock output implemented — after all, it would only have been a matter of rewriting the software, not changing the hardware.

Used in conjunction with a multi-timbral synth module like the Yamaha TX81Z, Roland D110 or Casio VZ8M, the Omnichord becomes a very flexible controller. Select some appropriate sounds, assign them to the correct MIDI channels and play away. You have all the power of MIDI sounds under your control, without any musical skill required to play them.

Of course, MIDI music data from the Omnichord could also be recorded into a computer-based sequencer, then edited and replayed on your synth modules. If you just want to strum a few chords in an experimental manner, put your sequencer in record and Omnichord away — unlike a guitarist, you'll have a useful record of your musical doodlings.

Despite its MIDI limitations the Omnichord is a fascinating prospect. Ask your local music shop for a demo if you're sceptical!

# INSIGHT

## LIVING ON MERCURY



**M**ercury Communications is British Telecom's only real competitor in the UK arena of telecommunication, unless you are lucky enough to live in Hull (where the local company offers unlimited local time for one unit and various other goodies). Elsewhere you choose between traditional BT and new dynamic Mercury.

Mercury has been concentrating its efforts on business and industrial customers. The opportunity is there, however, for punters such as you and I to use its pristine networks to talk to Auntie Floss in Glasgow and Martin Smith in Croydon. Should we bother?

Well Mercury call rates are significantly below those of British Telecom for all national (between 15-20% saving) and international (up to 14%) calls. Only on local connections do BT outperform Mercury.

So why hasn't the entire British public rushed to take a Mercury account? Where are the roundabouts that balance the slides?

The biggest single problem with Mercury operation is that there is no such thing as a Mercury Line. The only way for a private householder to connect with the Mercury network is to have BT put in a line then apply for a Mercury authorisation code to change networks at the local exchange.

This means that Mercury users have to pay basic standing charges to both companies. So at what point does it become profitable to switch to Mercury?

### The Big Blue Button

One necessity for Mercury subscribers is a special telephone with the Mercury blue button. Prices are still significantly above those of normal telephones but are dropping all the time. Answercall's Hollywood 10 unit, for example, retails at just £29.99 and

features 10 memories plus redial as well as the all-important Mercury button.

### The Cost Equation

The telephone can be regarded as an investment — the money saved by removing BT's equipment rental charge will in any case pay for the aforementioned Hollywood 10 pretty pronto.

Then there is the Mercury subscription cost — happily almost negligible at £8.62 for a whole year. Of course on top of that you'll be paying BT line rental every quarter but if you abandon BT altogether you may get a 'low usage' reduction on this.

Most people settle on the cost-effective option of using both networks now available to you. Select BT for local calls and the Mercury button for further afield.

So balancing the two sides of the equation, you only need to save £8.62 a year for Mercury to pay for itself. With Mercury's present call rates you can reckon to save that if your bills at the moment are about £60 a quarter, with a reasonable percentage being national calls. If you regularly make international calls then get on Mercury immediately! The savings make Mercury a positive boon.

### Making A Call

Mercury calls do take a little longer, increasing the connection time by about half as much again compared with going straight through BT. Calling Nottingham from London through a non-System X exchange into Mercury and out the other end (pause for breath somewhere around Watford Gap) took me 27 seconds last night, the same number through Telecom

was 19 seconds. The extra time might be a bind for business callers that never put the phone down (those water shares might have fallen a pound or so in those eight seconds) but at home on a Sunday by the fire it makes little odds.

### Things That Go Eeeek In Your Ear

However the Mercury dialling tone (it sounds when you hit the Mercury blue button) is a positive irritant. A high-pitched whistle sufficient to give your average pet poodle a Rottweiler mentality. Pour quoi? as they say on the Minitel network. A buzz would be sufficient, the Mercury eeeek just hurts. You learn to dial holding the phone at arm's length — every once in a while you forget and get your ear blasted. Why didn't they choose a soothing boop? It's annoying but sit back and think of the money you're saving.

### Spot The Swine

I'll tell you the reason I went on Mercury in the first place. I live in Ealing and, nice area as it is, we're not yet on a digital exchange. Consequently itemised billing is not an option. Living, as I do, with anything up to eight highly-communicative maniacs, this can be something of a problem.

Mercury not only gives you itemised billing but introduces the sensational concept of cost centres. This is aimed, one assumes, primarily at the business sector to identify the swine that's making calls to Miami. The system is equally useful in a house such as my own.

When you register you get the choice of having two digit or three digit cost centres, or ignoring the system. You dial the cost centre immediately after pressing the Mercury button, before you dial the main number. The bill arrives split into cost centres and everyone pays their share. No arguments. It helps.

### Paying The Bill

Perhaps it's because it's still in its infancy but Mercury is extraordinarily helpful when it comes to accounts, bills and generally parting with the luka. One time when someone was leaving the maison chez-moi, we needed an interim bill to get their share paid before they left. Mercury assessed the account and faxed me the results in 48 hours (try that on BT and take a major holiday while you wait).

Also I neglected to pay the last Mercury bill on time (purely as research for ETI you understand). Three months later I still hadn't received a reminder from Mercury. Courtesy taken to the degree of incompetence some might say, but they caught up with me eventually...

### The Signals Are Clear

There are a lot of rumours around that connecting Mercury through BT and back again gives you appalling s/n, that you get wrong numbers constantly, that you get nothing even more often. Nah. We've never had any problems. True, the guys in the house that modem to work always choose to go through BT but they admit they have no proof, they just minimise their connections.

In conclusion, my household and I utterly recommend Mercury to anyone who uses their phone as more than a household ornament. You save money, you solve arguments, you gain the status symbol and you annoy BT. Who could ask for anything more?

**Clement Cross**

*There remain parts of the country not yet able to join the Mercury network. To check if this means you — or for other Mercury information — contact Mercury on free-phone (0800) 424194.*

## OUT ON THE STREETS

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# THE INFINITE BAFFLE

## Loudspeaker enclosure design

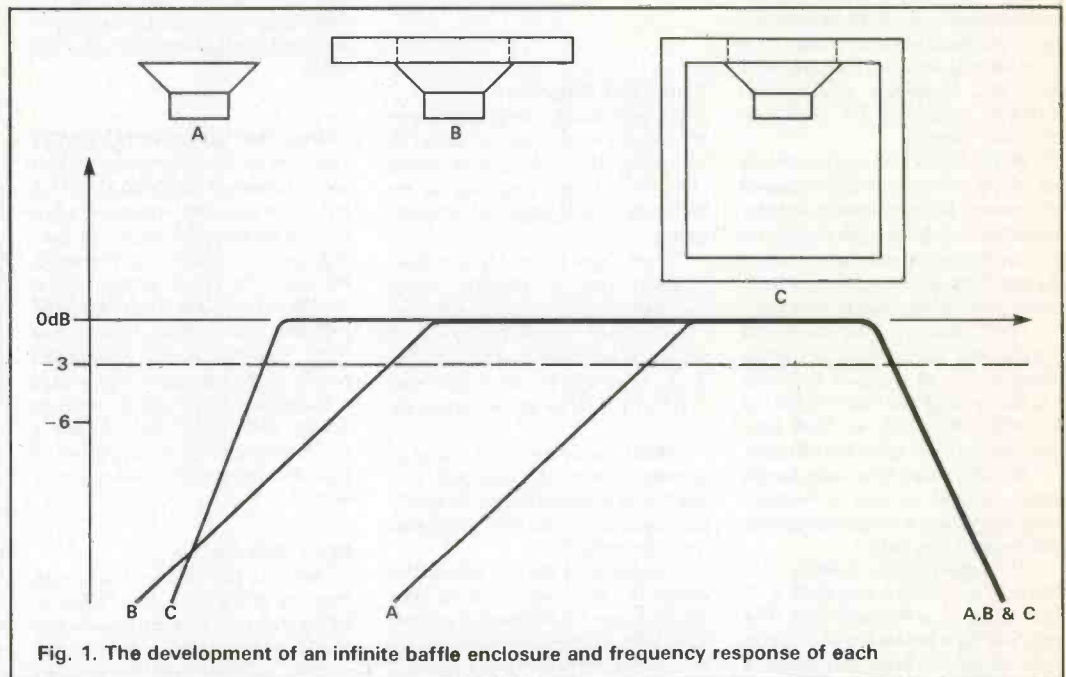


Fig. 1. The development of an infinite baffle enclosure and frequency response of each

*Jeff Macauley turns to infinite baffle enclosures and presents the case for optimum design*

**I**n any reasonably-sized library you will be confronted with shelves heavy with electronic text books covering every imaginable aspect of electronics. Yet if you try to find out how to design a speaker all you get is a rough description of the various enclosure types. No mathematical guidance and precious few practical examples to follow. This state of affairs is even more surprising considering that the UK's main hi-fi claim to fame has been the quality of our speaker systems.

The formulae and methods detailed here are not the work of any one man, they represent the fruits of research by many-too-many to mention in fact. I have written this article (and the other on reflex enclosures) so they might stimulate others to design and build. All the equations presented here are within the reach of a scientific calculator coupled with a basic knowledge of algebra.

Right, to business. Having discussed reflex speaker systems it's time to take a look at the alternative. Probably the simplest form of speaker enclosure available to the home constructor is the closed box of infinite baffle. Many readers must have made one of these by simply building a conveniently sized box and mounting a speaker in it. If you're very lucky you might get a passable result this way but the best way to design an enclosure is by using a little maths.

### No Case, No Bass

Before delving into the design procedure in detail it is just as well to go back to basics. First consider what happens when you use a speaker without any cabinet. The first thing you notice is a complete lack of bass. This is because the wavelengths of bass frequencies are very long compared to the diameter of the speaker. Since the rear of the cone is radiating bass

in antiphase with the front of the cone, an acoustic short circuit occurs — the front and rear (diffracted) radiation cancel each other out reducing the amplitude. Higher frequency sounds have a wavelength small compared to the driver diameter, are diffracted less, and less cancelling occurs.

The critical frequency (below which the response rolls off) occurs where the diameter of the cone is equal to a half wavelength of the radiated sound. One obvious solution to the problem is to mount the speaker on a large flat board — a baffle (Fig. 1). The rear radiation from the cone then has further to travel to reach the front and the low frequency response is thus extended. Again bass roll-off occurs at a frequency where the minimum dimensions of the baffle is equal to a half wavelength.

You don't see many open baffle speakers these days and you can see why when you calculate minimum dimensions for a baffle to respond to say 40Hz. This comes out at 14.1ft (4.29m)! However the baffle mounting just described has some advantages over a conventional speaker. For example the rate of roll-off is a gentle 6dB/octave down to the speaker's resonant frequency. Also there are no internal box resonances to contend with.

If you take the baffle and fold it into a box you get the infinite baffle (IB) enclosure. This method of mounting has the advantage that the rear radiation is prevented from reaching the front. However, the idea does impose restraints of its own, the most serious being that the enclosed volume of air in the cabinet makes the speaker's surround look stiffer and raises the resonant frequency. Below the resonant frequency the response of the speaker will roll-off rapidly at 12dB/octave. The rise in resonant frequency explains why even speakers with a free air resonance around 25Hz cannot respond adequately

below 50Hz when mounted in a reasonable case.

When discussing reflex speaker theory in ETI July 1989 I used the theory of Theille and Small to predict enclosure response. The same theory also describes IB designs. An IB can be represented as an equivalent circuit, in this case a second order high pass filter. The main differences between filters of the second order, apart from their roll-off frequencies is the Q. As in tuned circuit theory the Q determines the peaking or otherwise of the filtering pass band.

Figure 2 shows the effect of various values of Q on a high pass filter's response. To make things clear I have superimposed the curves for the same turnover frequency. The first thing to notice is that a Q of greater than 0.707 shows a peak in the response. The .707 Q curve corresponds to the Butterworth filter which has the flattest curve for the least amount of ripple in the pass band. Low Q curves show a substantial amount of roll-off but very low ripple. These curves are representative of the response obtained in an IB enclosure simply by adjusting the volume. How then do you obtain a useful result in practice?

Once again the answer can be obtained by applying filter theory and to do this effectively we need to know the speaker's parameters  $V_{as}$ ,  $f_s$  and  $Q_{ts}$ . These should be included in the speaker data sheet.

$V_{as}$  is the equivalent volume of air such that its compliance equals that of the speaker. Frequency  $f_s$  is the free air resonant frequency of the driver and  $Q_{ts}$  is the effective Q of the resonance, again measured in free air.

In a practical cabinet what Q should be aimed for? Well for starters it rather depends on the kind of musical representation you like. A Q of 0.7 is held by many to be the optimum and has the property that the resonant frequency measured in the case is equal to the -3dB point. As you might expect from inspection of the Q=0.5 curve, the -3dB point here is substantially above the resonant frequency. The higher Q curves will give better results on rock material producing an (artificial) bass emphasis. Many highly regarded speakers have been designed with higher values than 0.707. However anything above 1.2 should definitely be avoided if realistic reproduction is your aim.

## The Maths

In order to understand how to proceed let's take our old friend the B110 as an example. The published parameters for this driver are  $V_{as}=0.83\text{cu ft}$ ,  $Q_{ts}=0.31$  and  $f_s=37\text{Hz}$ . To design to a given Q we make use of the equation:

$$\frac{Q}{Q_{ts}} = \frac{f_c}{f_s} \quad \text{eqn 1}$$

Where Q is the desired response curve and  $f_c$  is the resonant frequency of the driver mounted in the cabinet. So for a Q of 0.7 we can rearrange equation 1 to  $f_c = f_s Q / Q_{ts} = 37 \times 0.7 / 0.31 = 83\text{Hz}$ . To find the corresponding cabinet volume we must make use of a second equation.

$$V_b = \frac{V_{as}}{\left(\frac{Q}{Q_{ts}}\right)^2 - 1} \quad \text{eqn 2}$$

where  $v_b$  is the required cabinet volume. Putting figures into the equation for the B110,  $V_b = 0.83 / ((0.7/0.31)^2 - 1) = 0.202 \text{ cu ft}$ .

As I previously mentioned the -3dB point varies with the chosen Q. Here we can explode a popular myth about IBs that the response extends downward

with increasing cabinet volume. What does happen is that the resonant frequency measured in the assembled cabinet gets lower with increasing volume. This is not the same thing as the -3dB point. However knowing the resonant frequency of your driver in the cabinet is a useful check, if only to show whether the speaker's published parameters are correct.

To find  $f_c$  we can use the following equation,

$$f_c = \frac{Q \cdot f_s}{Q_{ts}} \quad \text{eqn 3}$$

The -3dB point can be determined from applying the equation:

$$f_3 = \left[ \frac{\frac{1}{Q_{tc}^2} - 2 + \sqrt{\left(\frac{1}{Q_{tc}^2} - 2\right)^2 + 4}}{2} \right]^{1/2} f_c \quad \text{eqn 4}$$

To illustrate the result of increasing cabinet size we can construct Table 1, using the B110 with decreasing Q.

Several interesting things can be seen from examination of this table. Firstly as the cabinet volume is decreased the -3db point goes lower until  $Q = .707$ , thereafter the -3db point rises again. Secondly the Q of the cabinet decreases with increasing volume and tends towards a limit ( $Q_{ts}$ ) when the cabinet has an infinite volume.

Frequency  $f_c$  decreases with an increasing cabinet volume, the limit being  $f_s$  when the cabinet is infinitely large.

Lastly, above  $Q = 0.707$  there is a peak in the response,  $f_p$ , in the table of amplitude pk dB. To complete this section  $f_p$  and  $p_k$  can be determined from the following equations:

$$pk = \sqrt{\frac{f_c}{1 - \frac{1}{2Q_{tc}^2}}} \quad \text{eqn 5}$$

$$f_p = 20 \log_{10} \left( \frac{Q}{Q^2 - 0.25} \right)^{1/2} \quad \text{eqn 6}$$

In essence this is all there is to IB design, however there are some useful extra techniques that can help you reach your design target. It is possible to tweak both  $Q_{ts}$  and  $f_s$  within limits to achieve a given response. To understand how we must again go back to basics.

At resonance the speaker cone can be modelled as a mass suspended on a spring. In our model the cone mass is the mass and the compliance of the suspension is the spring. If the mass is pulled downward and then released the system will oscillate at its natural frequency ( $f_s$ ). The time the system takes to come to rest is determined by the losses in the system ( $Q_{ts}$ ). Both the resonant frequency and the  $Q_{ts}$  can be modified by adding more mass to the system. This both lowers the resonant frequency whilst increasing the Q. The moving mass of the cone is usually in the order of 10-30 grammes. Hence small mass increases can have quite an effect on the system characteristics. The price that has to be paid is a lowering of efficiency.

To put some maths to the problem the resonant frequency of a driver is determined by the cone mass  $M_c$  and the surround's compliance  $C_m$  such that

$$f_s = \frac{1}{2\pi \sqrt{C_m M_c}} \quad \text{eqn 7}$$

```

90 REM **SET UP SCREEN**
100 c1$=CHR$(27)+"E"+CHR$(27)+"M"
110 k=2.7*10^-8
120 PRINT c1$;"This program calculates IB enclosures given driver parameters":PR
INT
130 REM**CHOOSE PRINTER**
140 PRINT"To continue press any key":WHILE INKEYS="" :WEND
150 PRINT c1$
160 INPUT"Printer output; 1=yes;0=no";c
170 REM **ENTER DRIVER DATA**
180 INPUT"Driver Name ";a$
190 INPUT"Free air resonant frequency;fs":fs
200 INPUT "Equivalent compliance volume;Vas";vas
210 INPUT "Total Q;qts":qts
220 INPUT"If known electrical Q;qes";qes
230 REM **CALCULATE DRIVER DISPLACEMENT**
240 INPUT"Driver diameter in inches";d
250 d=((d/2)*0.025)^2*3.142*0.006
260 REM**CHOOSE ENCLOSURE SIZE,OR NOT**
270 INPUT"To calculate parameters for known volume press a and enter";e$
280 IF e$="a" THEN INPUT"Enclosure volume in cu ft";v1:a=vas/v1:qtc=qts*(a+1)
0.5)
290 IF c=0 THEN PRINT c1$;"VAS = ";vas;" ";Fs = ";fs;" ";Qts = ";qts ELSE
LPRINT"VAS = ";vas;" ";Fs = ";fs;" ";Qts = ";qts
300 IF c=0 THEN PRINT "DRIVER = ";a$:PRINT ELSE LPRINT"DRIVER = ";a$:LPRINT
310 IF c=0 THEN PRINT " Qtc"," Vb;-cu ft"," -3db Hz"," spl;1W/1m"," Vpeak db","
fpeak Hz" ELSE LPRINT " Qtc"," Vb;-cu ft"," -3db Hz"
," spl;1W/1m"," Vpeak db"," fpeak Hz"
320 PRINT
330 IF e$="a" THEN qes=0.3:fp=0:p=0:GOTO 380
340 IF qes=0 THEN qes=0.3
350 p=0:fp=0
360 REM**CALCULATE PARAMETERS**
370 FOR qtc=0.5 TO 1.5 STEP 0.1
380 IF qts>qtc THEN 460
390 fc=(qtc*fs)/qts
400 a=((qtc/qts)^2)-1:vb=vas/a
410 q1=qtc^2:q2=(1/q1)-2:q3=q2+((q2^2)+4)^0.5:q4=(q3/2)^0.5:f3=q4*fc
420 no=(k*(fc^3)*vas*vb)/(Qes*(vas+vb)):spl=112+10*LOG10(no)
430 IF qtc>0.71 THEN 490
440 IF c=0 THEN PRINT INT(10*qtc)/10,vb,f3,spl,p,fp ELSE LPRINT INT(10*qtc)/10,
vb,f3,spl,p,fp
450 IF e$="a" THEN 470
460 NEXT
470 INPUT"To enter another driver enter e";e$
480 IF e$="e" THEN PRINT c1$:GOTO 100
490 p1=(qtc^4)/((qtc^2)-0.25)^0.5:p=20*LOG10(p1)
500 p1=1/((2*qtc)^2):fp2=(1-p1)^0.5:fp=(1/fp2)*fc
510 GOTO 440

```

Listing 1. Computer listing for enclosure optimisation

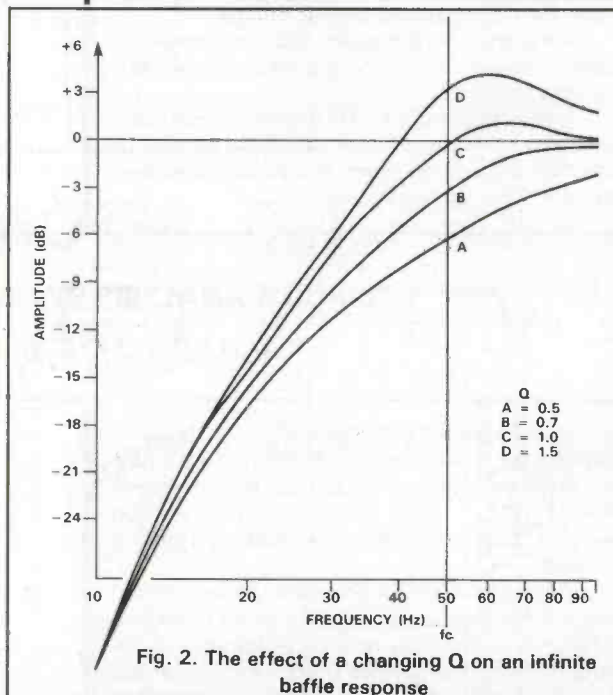


Fig. 2. The effect of a changing Q on an infinite baffle response

Q	Vb, cu ft	fc Hz	f3 Hz	fp Hz	Pk db
1.4	0.0427	167	118	179	3.5
1.3	0.0500	155	112	168	2.97
1.2	0.5935	143	105	158	2.41
1.1	0.7161	131	99	147	1.83
1.0	0.8824	119	93	138	1.25
0.9	0.1117	107	89	130	0.68
0.8	0.1466	95	85	122	0.21
0.7	0.2025	84	84	-	-
0.6	0.3022	72	86	-	-
0.5	0.5183	60	92	-	-

Table 1. B110A in infinite baffle enclosures

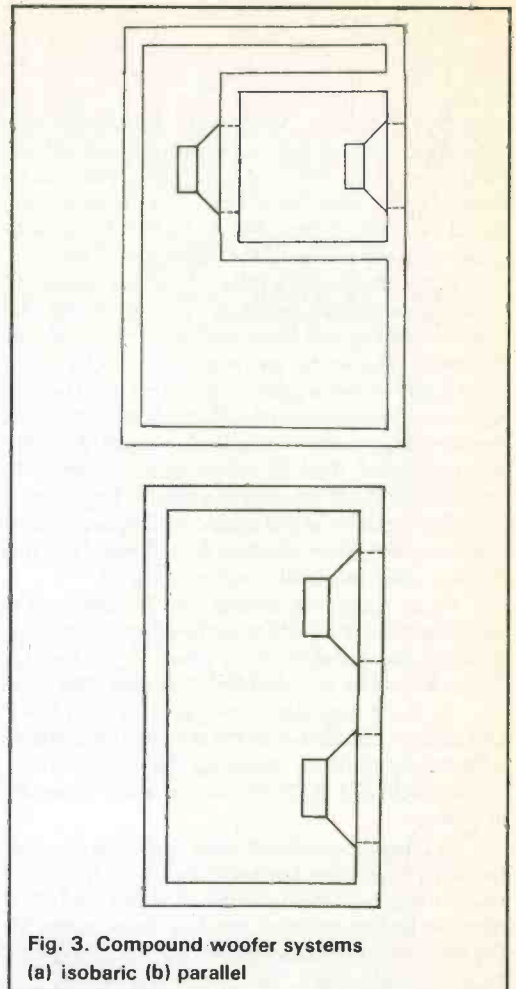


Fig. 3. Compound woofer systems (a) isobaric (b) parallel

The values of  $C_m$  and  $M_c$  can be obtained from the driver data sheet. Rearranging this equation

$$M_1 = \frac{1}{C_m (2\pi f_{s1})^2}$$

where  $f_{s1}$  is the desired resonant frequency and  $M_1$  is the moving mass required. The amount of mass to add is  $M_1 - M_c$ . Blu-tac works quite well in this application!

Note that this procedure will also affect the  $Q_{ts}$  of the driver. From equation 1,  $f_c Q_{ts}$  is a constant for any given driver. The new  $Q_{ts}$  ( $Q_{ts1}$ ) can be found from:

$$Q_{ts1} = Q_{ts} f_c / f_{s1}$$

Having changed the driver's characteristics use the formulae to obtain your desired performance.

Another useful wheeze is to simply change the  $Q_{ts}$  of the driver. This can be simply achieved by adding a resistor in series with the speaker. Here again the cost is a loss of efficiency.

To achieve this, let's take a practical example. Lets suppose we have built the B110 into a 0.512cu ft enclosure to give us a Q of 0.5. To change the Q to 0.7 and hence lower the cut-off frequency we proceed as follows. First we need to know the electrical Q of the driver ( $Q_{es}$ ) and the mechanical Q ( $Q_{ms}$ ). These can be obtained from the data sheet. For the B110  $Q_{es}$  is 0.33 and  $Q_{ms}$  is 6.7. We also need to know the voice coil resistance  $R_e$ , 7.1R. This last parameter is easily measured with a multimeter.

$Q_{ts}$  is adjusted by increasing  $Q_{es}$  since  $Q_{es}$  is dependent upon the drive signal impedance.

(As an aside the speaker parameter  $Q_{ts}$  and  $Q_{es}$  are quoted when the driver is fed from a zero impedance source. If you use a modern transistor amplifier with low impedance speaker leads this assumption will produce accurate results. However



if you are the proud owner of a valve amplifier with a sizeable output impedance, 0.5R say, then the equations will be altered. The speaker design is less well damped. This is surely the reason that many cognoscenti think that the bass response from valve amps is a little boomy. However the cause is not the amplifier per se but the speaker which has been designed on the assumption of zero output impedance.

To get back to the business in hand:

$Q_{es1} = Q_{es} ((R + R_e) / R_e)$ , where  $R_e$  is the voice coil resistance and  $R$  is any resistance in series with the driver.  $Q_{es1}$  is the new value of  $Q_{es}$ .

$$\text{Also } \frac{1}{Q_{ts1}} = \frac{1}{Q_{es1}} + \frac{1}{Q_{ms}} \quad \text{eqn 8}$$

So  $Q_{ts1}$  is proportional to  $Q_{es1}$  which itself is proportional to  $R$ . From equation 1:

$$f_c = Q_e f_s / Q_{ts} = 37 \times 0.5 / 0.31 = 59.7 \text{ Hz}$$

$$Q_{ts1} = Q_{ts} f_s / f_c = 0.7 \times 37 / 59.7 = 0.43$$

$$\frac{1}{Q_{es1}} = \frac{1}{Q_{ts1}} - \frac{1}{Q_{ms}}$$

$$= 1 / Q_{es1} = (1 / 0.43) - (1 / 6.7) = 2.178$$

$$Q_{es1} = 1 / 2.178 = 0.459$$

Now  $Q_{es1} = Q_{es} ((R + R_e) / R_e)$ ,

$$\text{so } R = R_e (Q_{es1} / Q_{es}) - R_e$$

$$= (7.1 \times 1.39) - 7.1 = 2.76R.$$

A 2R7 will do. The result will be to extend the -3dB point from 92Hz to 60Hz since with a Q of 0.7  $f_3 = f_c$ .

Finally a word about compound woofer systems. There are basically two different ways to implement

such a system. Firstly you can simply mount two identical drivers in the same case and wire them up in parallel (Fig. 3a). With this arrangement all the equations will work but remember that  $V_{as}$  is doubled compared with one unit. In practice this means double the enclosure size for a given bass extension. In fact if you use  $n$  identical drivers in a cabinet then the effective  $V_{as}$  of the combination is  $n$  times that of a single unit.

The other way of using two speakers is to place one behind the other as shown in Fig. 3b. This is the famous 'Isobaric' principle as used in the Linn Sara for example. It is covered by a world patent but this doesn't mean that we can't tell you about it. The advantage of using two speakers in this way is that the  $V_{as}$  is effectively halved. This means that the bass extension is doubled for a given volume, or alternatively you can get the same results with a half-sized cabinet as you would using a single driver. A short tunnel is used to acoustically connect the drivers together. Experimenters in the States have found that some deterioration in the midrange occurs. This can be cured though by putting a choke in series with the inner speaker.

Although the equations presented enable good designs to be produced without problems, I have included a computer program (Listing 1) to do the hard work. As with the 'Optibox' program presented with the reflex article this was written for an Amstrad 8256 but can easily be converted to other machines and should run as is on any IBM compatible machine.

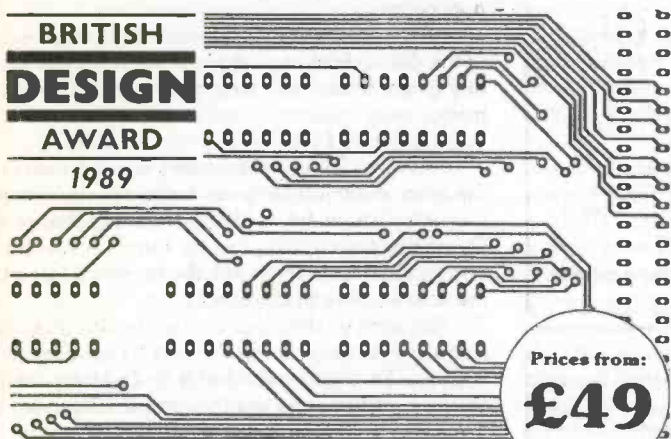
Again, when converting to other dialects of BASIC remember the following: Line 120 is used to set a clear screen instruction. The 'while inkeys\$ = ' ;' instruction simply pauses the program until a key is pressed. Other machines will have equivalent instructions.

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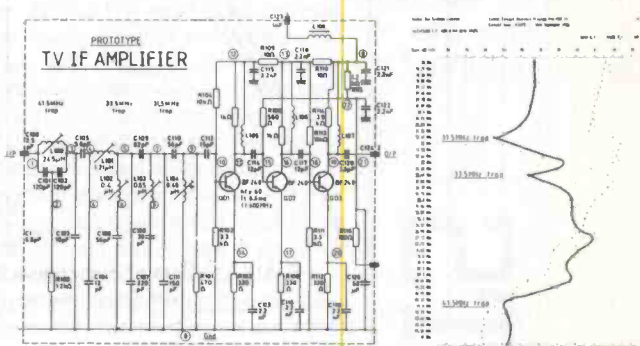


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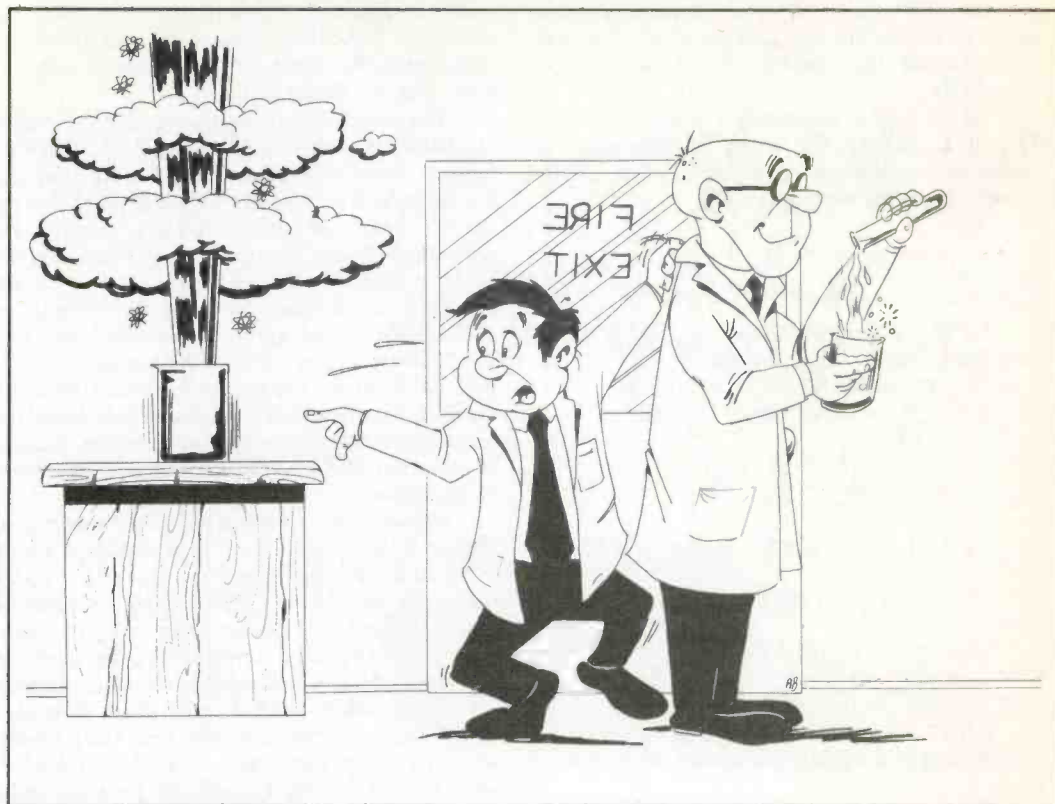
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# PATENTS



## AND THE ART OF INVENTION

*Taking out a patent can be confusing and costly. Not taking out a patent can be worse. Pat Alley tackles the obstacle course head on*

# PATENTS

**N**ecessity is the mother of invention. So the saying goes and there are plenty of people to vouch for it. You do not have to be a brilliant scientist to invent something. Some of the biggest money-spinners have been in low tech areas. You do not necessarily have to be an expert in the field of your invention. It is often the free thinking but inexperienced newcomers who have the gall to try and achieve some goal contrary to methods used by experts steeped in tradition.

Conceiving the idea unfortunately is not enough. First you have to recognise that your 'baby' has the potential of being classed as an invention. The idea then has to be put into practice and it must work.

Then comes the hard part — trying to convince the right people to back it. Assuming you get to this stage you are still not out of the woods because now comes the Licensing Agreement. Since this will bear the fruits of all your endeavours it is perhaps the most important step of the whole procedure. Very few inventors end up as rich men. In fact many end up much poorer. It is with this in mind the following information is given.

### The Invention

An invention must be something tangible, not merely an idea or a discovery. For example if one day you discovered that adding some herb to a dash of butter formed ice crystals this would most probably be discounted as a patent. However if you put it to some good use by making an ointment to simultaneously employ as a cold compress and skin lubricant to

prevent soreness then it most probably would be patentable.

An invention must not be obvious to an expert in that field. For example a solution to a particular problem circuit (solutions is what inventing is all about) may be provided by negative feedback. In this case a patent is unlikely to be allowed since the solution would be classed as obvious unless the method of applying the feedback has virtues which may not be immediately apparent or are greater than might have been expected from the component parts.

Such an historical example was the push-pull amplifier where the particular method of combination exceeded the mere conventional coupling of two active devices.

Incidentally obviousness is not only very subjective but must be applied at the time it was novel. An invention must be novel. That means it must be new and unpublished. At one time something invented far afield could be introduced later into the UK by another person as an invention. However, with today's vastly improved forms of communication the novelty of such a patent would be destroyed and if by some mischance it was awarded it could be attacked on these grounds later.

This illustrates the point that the granting of a patent does not prevent it being declared invalid afterwards on more than one grounds. Publishing details of an invention before it is patented can be grounds for invalidating novelty. You may get away with it if it is published in a file marked 'Confidential' within the close confines of company. Even this may be doubtful if the person attacking the patent can give evidence that it was circulated to someone outside the



privileged circle (such as himself). The spoken word can also destroy novelty. There is only one insurance policy against falling foul of any of those rules and that is to submit a provisional patent as soon as the invention is thought of.

## Provisional Patent

To take out a provisional patent is a fairly simple procedure and (unless you are a commercial enterprise and expense is not too important) you do not need the services of a patent agent at this stage if you follow a few simple rules. Many pages could be written on the procedure but who better to explain it than the British Patent Office themselves. A phone call or a letter from you will bring its free publication *'Introducing Patents — A Guide for Inventors'* winging its way through the post to land on your doormat. The information is clearly written, easily understood and extremely informative. At the same time write to the British Technology Group for its publication *'Help for the Inventor'*.

The cost of taking out a provisional patent is currently £15 and for this modest sum your invention (if indeed it is deemed later to be an invention) is protected. Its priority dates from the time you submit details of the provisional patent to the Patent Office.

A few tips. Although at the time you submit the application you may not have finalised the exact form of the invention, or indeed even how you intend to present it, make a full disclosure of all you have accomplished so far. If nothing else this establishes a priority date of all that information and in later years may prove crucial — as it did in my own case.

Once a provisional patent has been submitted you have one year (with a three month extension for a UK patent) in which you get your invention into its final form. In the interim you may have modified the original ideas or made new discoveries not discovered in your original application. For a further £15 you can submit an additional provisional patent.

This is important as can be illustrated by my own personal experience. I submitted an application on 1st December 1978 disclosing facts A, in February 1979 facts B, in May 1979 facts C and in August 1979 facts

D before making a final application on 30 November 1979 citing the four provisional patents. The patent was subsequently granted. In 1981 a competitor's patent came to light similar to my own, a more common occurrence today as new technology across a broad front stimulates similar ideas in others as a solution to old problems.

The competitor had not bothered with provisional patents but had submitted his final patent in June 1979 — it was subsequently granted. This can happen where two similar patents are being processed at the same time by different examiners and is yet another reason why a patent may be invalidated after it is granted. Fortunately for me the competitor's patent did not progress so far as my own and all that he claimed was based on information A + B which I had already disclosed in my provisional applications of December 1978 and February 1979. So although his patent was granted before mine, my priority took precedence. A copy of my patent was sent to the competitor by my sponsor company.

Note you must never threaten an 'infringer', even with legal action. Sending a copy of your patent is acceptable and considered a fair warning that legal action is likely to follow. Shortly afterwards my competitor allowed his patent to lapse having spent thousands of pounds in getting it. Both my sponsor company and I were quite relieved that what could have ended up in costly litigation had been resolved. On reflection the chances are that my competitor actually discovered the invention before me but perhaps decided to develop it in secret in case this took longer than 12 months. This could have been the reason why he was able to dispense with a provisional patent and go straight into the final patent stage in June 1979. This illustrates the virtues of submitting a provisional patent at the earliest opportunity.

Another reason for early submission is that most would be inventors need to find a sponsor company to help develop it and which will later manufacture it under license to you. Without a provisional patent most commercial companies will not be interested, not so much because you have no protection but because it may compromise *them*. They cannot be sure you have not written to others, deemable as publication

which may be used later to attack the invention's novelty. On the other hand armed with a provisional patent you can safely divulge details of your invention.

If the company is not interested and sends a rejection letter, you can assume it is genuine even if you feel they will be sorry afterwards. (The classic example of this is Mr. Ron Hickman who left several well-known companies gnashing their teeth after turning down his Workmate which Black and Decker didn't). With a provisional patent you can also be most reassured that the company won't pinch your idea. For them to develop your idea without your licence is the road to ruin. Not only will they bear the expense of development but could end up later having to pay you heavy damages for infringement. For this reason if companies are interested and feel your idea even has a tinge of merit they will often pay you for a short term exclusive right to investigate it further.

## Collecting Your Just Reward

So how do you go about making your fortune once you have this great idea. First submit a provisional patent then send a short resumé of what you have invented to all the companies you feel may be interested, starting with the big names. To compile such a list may involve hours of research down at the library studying directories such as *Kompass*, reference to trade magazines and making general enquiries.

That is the hard way. A much easier and very cost effective way is to join the *Institute of Patentees and Inventors*. The Institute has several useful functions. Besides sending a periodic journal it gives general advice to inventors. If you wish it will evaluate your invention including an assessment of its value — a special advisory panel exists for this purpose. The Institute also has many company members able to provide a link between inventors and manufacturers. Most useful is that for a nominal fee the Institute will include abbreviated details of your invention in a periodic bulletin circulated to hundreds of manufacturers. Replies from interested manufacturers are passed straight on to you. Compare this service with those of professional companies set up to help inventors exploit their inventions but demanding hundreds and sometimes thousands of pounds up front from the inventor, with no guarantee of success.

Let us assume for purposes of illustration that you receive say four replies from interested companies. By this time if at all possible you should have built a working model of your invention. This is not absolutely essential if it is acceptable as being outside the realms of a one man effort but without something to demonstrate that your invention will work (no matter how Heath Robinson its construction), your invention is still no more than an idea. Having replied to the letters expect each company to make arrangements to send a representative along for a demonstration. If your model is portable they may ask for a demonstration at their works.

The story from now on can only be given as representative of what may happen — it can make many twists and turns but the sequence of events here is reasonably typical and covers the essential details.

Don't expect any fireworks when each company representative visits you. Most are middle management, technically orientated and report directly to a director of the company. Whilst they are not in a position to give any immediate decisions, normally by the time he leaves you will have a shrewd idea as to whether his company will be contacting you again. Whether you tell him of the other interested companies is up to you. Personally I do simply to keep everything above board.

Within about two weeks of the first visit you will either receive a very nice rejection letter or requesting typically an exclusive six month licensing agreement option for a sum of £X.

There is then nothing to stop you phoning the other companies informing them but be prepared for some very forceful characters of at least director status to phone you back accusing you of being unfair. They'll be unaware that you had approached others or tell you not to waste his time and to come back to him when you have decided how much you want for a six month option. Another may offer you the same sum for a three month option and yet another may tell you that whatever the others offer he will better it. Such sentiments are par for the course and serve as a warning not to expect any bouquets from outside your immediate family.

What you have is the makings of a potentially successful commercial product and what you have achieved so far is to establish that all the companies are sufficiently interested in your invention to check out its viability and perhaps have market research carried out.

However you now have a decision to make as to which company to go along with. It is at this point you appreciate how lucky actors are in having an agent to negotiate on their behalf. A 'resting' actor would most probably sell his services for peanuts just to get back to work. A new and inexperienced inventor, proud to have invented something acknowledged by his peers, will invariably under-sell it for fear of rejection. An agent is as hard-nosed as those he or she deals with, is well aware of the going rate and above all is not swayed by emotion. Alas inventors are not so well served as the actor. As already explained the few 'agents' who do exist not only want huge payments up front but also an exorbitant percentage of the royalty in perpetuity.

The decision as to which company to go along with is a crucial one since once the option period is over the time is nigh for the final patent application to be submitted. For this you will definitely need the services of a patent agent. You will also need the services of a good solicitor, preferably that of a commercial lawyer well versed in Heads of Agreement. Anticipating this:

- Try negotiating a three month option to allow time for another company to take an option if the first chosen company decides not to proceed after the option period.
- Ask each company if they are prepared to underwrite the costs of *your* patent agent and commercial lawyer. Traditionally the inventor will not use the sponsor company's patent agent. The patent will be taken out in the name of the inventor who will then be expected to grant an exclusive long term manufacturing licence to the company by way of a 'Heads of Agreement'.
- Find out what resources each company will put into assessing your patent. Will it also include development work in an effort to get the strongest patent possible?
- You could enquire if the interested companies are willing to take a non-exclusive option agreement at a much reduced cost (overall you would be no worse off financially) on the basis that one or two may drop out once they have assessed development costs and researched the market. Expect most companies to reject this idea since few are prepared to risk costly R&D only to be rejected later in favour of another company. Also this tactical move could be a dangerous one from the inventor's standpoint. If the invention proves to have great commercial potential one or more of the rejected companies, having now been wound

up, may be tempted to continue development and attempt to find a way round the patent. Indeed the underlying reason for most infringement actions is not that 'infringers' resent paying royalties to the inventor but stems from the inability to obtain a licence from an inventor tied by an exclusive contract to another manufacturer.

- Obviously the size and resources of each company is important. You may also ask each one what down payment they are prepared to offer if the option agreement progresses into a long-term licensing agreement. Also what royalty percentage they have in mind and on what price (manufacturing cost, manufacturer's price to the trade) will it be based on. This allows you to compare like with like.
- In the case of infringement ask each company what its policy is as to which party will bear the cost of commencing infringement action or defending an action against the validity of your patent. (Note that the granting of a patent is not an absolute guarantee the product will not infringe someone else's patent). On no account should the inventor bear these costs but it is best left that either party can take action as it sees fit at the time with the understanding that whichever party bears the costs enjoys the fruits of a successful action.

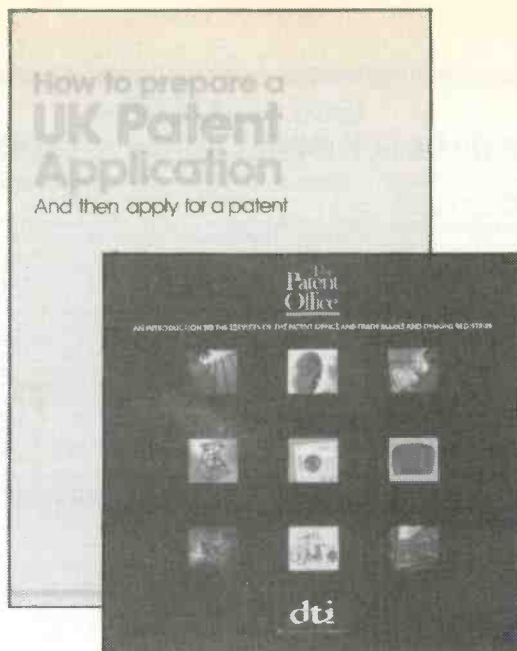
Assuming at least one of the companies gives all the right answers lose no time in choosing your patent agent and commercial lawyer, both of whom will be able to advise you. An 'Option Agreement' is normally drawn up by the licensee company's solicitor modified as necessary by the inventor on advice from his professional advisers. This agreement is typically a short document running to no more than two or three pages. It starts by identifying the parties to the agreement, the registration number of the provisional patent and the right of the company to enjoy an exclusive option for a limited period for the sum agreed. A typical period may be anything from three to six months and the sum anything from £2000 upwards depending on the maximum amount the company is prepared to spend. Typically the document will then go on to record that at the end of the period the agreement will automatically terminate but that if meantime the company wishes to exercise its option it can negotiate an exclusive license. Note the operative word is 'negotiate' so there are no pre-conditions.

Assuming the company decides to exercise its option, there is a bout of hard bargaining which may go on until well after you have submitted your final patent application. There are not typical royalty figures other than to say that if the invention is a large piece of machinery costing several thousand pounds and with a small sale, the licensor may seek 15% to 20%. If on the other hand the item is small, inexpensive and sold in very large numbers then anything from 1% to 5%, all figures usually being calculated on factory price (*ex-works*).

These figures are subject to compensating factors such as whether the licence is exclusive, do patents cover more than one country, is there a down payment, is there a minimum annual royalty (you normally insist on this so as to keep the company on its toes!).

The size of the company will also figure in the equation. Expect a lower percentage from a large company, compensating this with a larger volume of sales.

You may also negotiate for a higher percentage depending on the commercial quality and strength of your patent(s). Forecasting these can be very difficult. For example who would have thought that a small



workhorse table with a wooden vice called Workmate would turn out to be perhaps the most successful commercial invention in modern times. As to the strength of a patent this can only be definitively qualified once it has survived one or more infringement actions through the courts (once again the Workmate took on all comers). However there is in my opinion one method of gauging the strength by implication, centring on claim 1 of your final patent. It will be appreciated that a principle cannot be patented, only the apparatus itself based on the principle. However by the time a good patent agent has cleverly worded claim 1 he will to all intents and purposes have patented the principle. If there is no prior art (earlier patents in that field which will be made known to you) and the patent examiner allows this very wide claim 1 then you can assume you have a strong patent. However the more prior art there is, particularly if the patents are still currently in force, the more extensively your claim 1 has to be altered and added to on insistence of the examiner. You can assume your patent to be weaker.

Finally out of all the bargaining and negotiation a 'Heads of Agreement' document is formulated which can run to thirty or forty pages in order to cover every likely exigency.

So with all that completed you should be able to sit back in your patent (sic) leather armchair and let the royalties trickle or flood in. Unless of course you've had another idea in the meantime ....



## ADDRESSES

British Patent Office  
State House  
66-71 High Holborn  
London EC1R 4TP  
Enquiries 01 829-6910

Institute of Patentees and Inventors  
Staple Inn Building South  
335 High Holborn  
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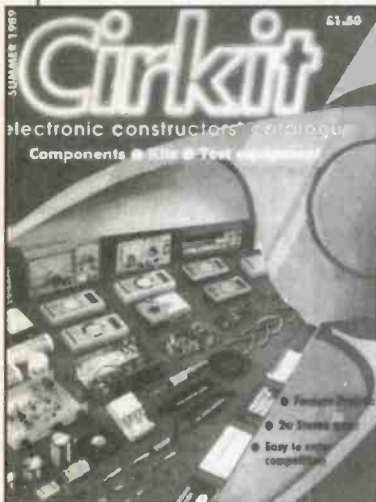
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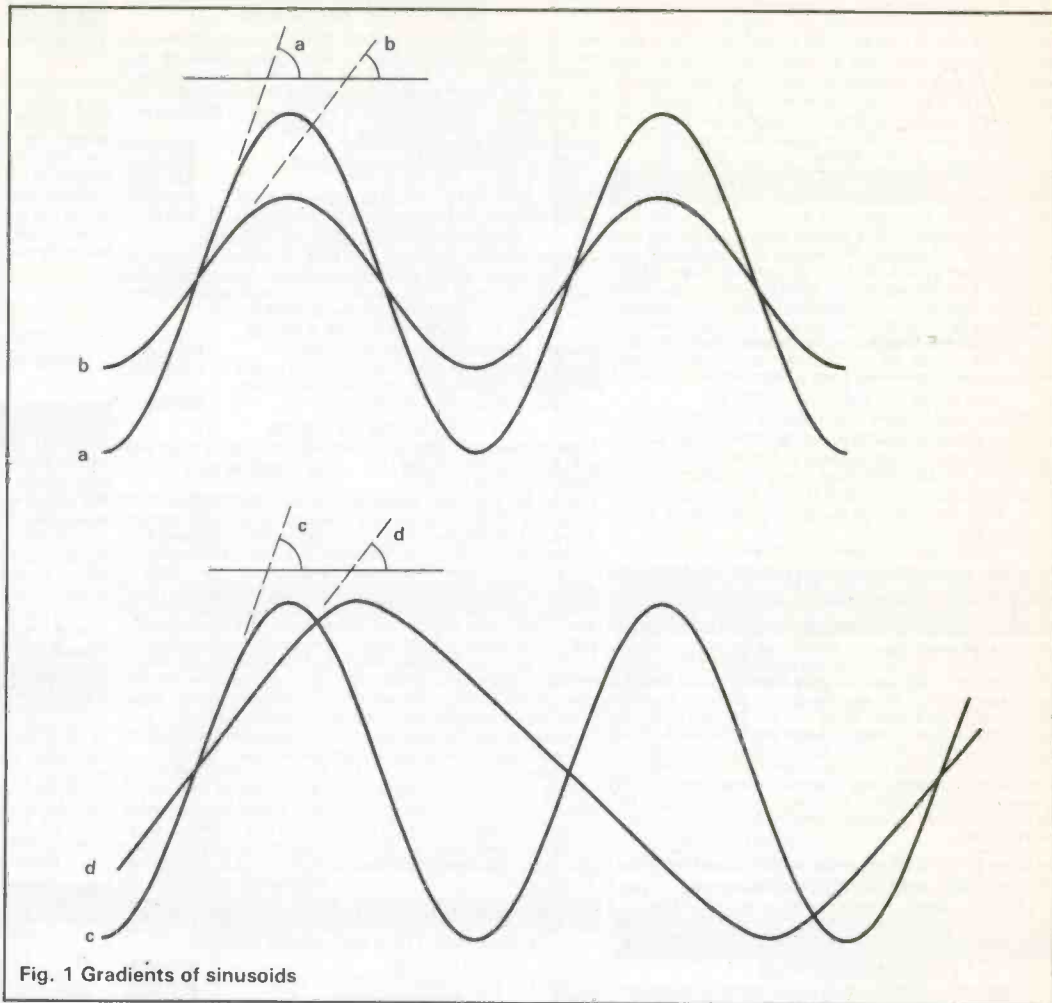


Fig. 1 Gradients of sinusoids

Continuing our story of measurement, Mike Barwise examines signal analysis

## TEST GEAR

**L**ast month we looked at plotters and oscilloscopes which produced an output (on paper or on a screen) while the signal under examination was present at the test gear inputs. This kind of equipment can all be classed as *real-time* instrumentation: the display is produced while the measured event is taking place.

Real-time instrumentation suffers generally from one major drawback: it is very difficult to use when the signal you want to look at consists of a *single unexpected* event such as a short pulse. The reason for this is twofold: firstly, it is difficult to get the event itself to start the recording quickly enough to ensure that early information is not lost, and secondly, particularly when using a scope, the record will be well-nigh invisible as it consists of a single passage of the bright spot which will fade away almost immediately. The pen recorder comes off better in this respect, but it is a very slow recorder (it has a low bandwidth).

This raises the final question concerning real-time instrumentation: how do you select gear to match your expected signal? The immediately obvious criterion of signal amplitude is only one of the two basic criteria. If your expected signal is in the nV ( $10^{-9}$ V) range you need considerable amplification (to make it bigger) to be able to see it, and if it is in the kV ( $10^3$ V) range you need a lot of attenuation (to make it smaller), so you don't blow up your scope.

### Real-time Bandwidth

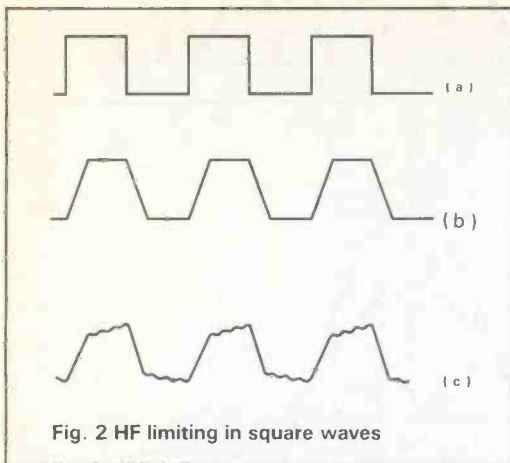
The second and less immediately obvious of the two

basic selection criteria is bandwidth. Here we have to go back to some fundamentals (albeit superficially). All waveforms other than sine waves consist of the sum of a set of sine waves of different frequencies. The sine wave is effectively the graph of the trigonometrical sine function. Its peculiar property in this strange world is that its varying rate of change accords best with the way things want to move. The curve consists of alternate acceleration and deceleration at the optimum rates for continuous smooth motion taking account of inertia. It follows that the sine wave is the easiest curve to draw with a pen on a moving arm or a moving electron beam.

I think we are all familiar with inertia: it takes more effort to get your wheelbarrow moving from rest than it does to keep it going once you are moving (it also takes more effort to get out of bed than it does to stay out once you have got up, this is also inertia of a kind). The sine wave is thus the waveform which can be followed fastest by any given piece of equipment. In fact, the electron beam of a scope can move very fast indeed: the normal limiting factor is the slew rate of the signal amplifiers in the scope.

The normal terminology for speed in test gear is bandwidth at  $-3$ dB. Let's look at what this means. When we considered active rectifiers, we used the term slew rate for the maximum speed at which the output of an amplifier can change its voltage when attempting to follow a changing input. Referring to Fig. 1a & b, we see two sine waves of equal frequency but different amplitude (voltage swing peak to peak). If you look at the sloping portion of any cycle, you will see that the angle to the horizon is greater for the large





amplitude signal than for the small amplitude signal. The angle of this slope represents the rate of change of voltage: the steeper it is, the faster the voltage is changing.

Now let us consider Fig. 1c & d. In this case, the amplitude of both sinusoids is the same, but the frequency of one is greater than that of the other. Once again we see that the angle of the sloping face of the waveform is greater for the higher frequency. The slew rate limit of our scope signal amplifier effectively defines a critical steepness of the sloping portion of any waveform appearing at the amplifier output. The net result of this is that if you attempt to amplify a signal with a combination of frequency and amplitude which would cause the maximum slew rate of the amplifier to be exceeded, the signal will be modified by the amplifier until it conforms to the imposed limit. As the amplifier cannot change the signal frequency, it does the only thing left to it: it reduces the signal amplitude until the signal gradient does not exceed the slew rate. In brief, excessively fast signals are attenuated.

OK. That's fine, but what is all this 3dB nonsense? The Bel (named after the guy responsible for your huge phone bills) is a unit of power difference (gain or loss). 1 Bel equals a power difference of 10x. This is (as in many other cases) rather too large a unit to be useful — it is defined in basic electronic units, rather like the excessively large Farad). To bring things into reasonable proportion, the deciBel (dB) is used. The easy thing to remember is that 3dB equates to a change of double or half. Remembering that power equals voltage multiplied by current ( $P = V \times I$ ) it is quite easy to work out that doubling the power in a circuit of a given resistance means multiplying the voltage by  $\sqrt{2}$  (1.4ish) and halving the power means multiplying the voltage by  $1/\sqrt{2}$  (about 0.7). Minus 3dB means a power reduction of 50%, so the voltage swing on your scope screen will be about 0.7 of the swing at the scope input when you reach the frequency specified.

The -3dB bandwidth limit of your scope is not, therefore, an absolute cutoff point. Any good quality scope will trigger at a considerably higher frequency. The bandwidth limit simply tells you when voltage measurements start to get a lot less precise.

For example, my Hameg (nominally 60MHz at -3dB) is actually 3dB down at about 65MHz, and will trigger reliably to more than 82MHz. The manual provided with the scope actually gives a table of expected amplitude multipliers at frequencies up to about 80MHz.

So far so good: now for the bad news. All this bandwidth information assumes that your signals are pure sinusoids (which they practically never are). For any other waveform of the same basic frequency, the steepest parts of the rising and falling edges will be

steeper. However, the problem is a little more complicated than this. A non-sinusoidal waveform, as I have suggested, consists of the sum of a set of sinusoids of different frequencies. Let's take the nastiest regular waveform: the square wave (Fig. 2a). The perfect square wave (actually impossible to generate) has a rise time of zero: its edge gradient is  $90^\circ$ . This means that the signal voltage changes from maximum positive to maximum negative in no time at all, which can't be done. If this was all there was to the problem we would expect a waveform out of our scope similar to Fig. 2b. However, the real result looks more like Fig. 2c. Why?

You can, in fact create a square wave by adding together the following sinusoids in the specified proportions:

$$f \times 1 + 3f \times \frac{1}{3} + 5f \times \frac{1}{5} + 7f \times \frac{1}{7} + \dots + nf \times \frac{1}{n}$$

where:

$f$  = the lowest frequency sinusoid (Hz)

$3f, 5f, 7f$  etc... = higher component frequencies

$\frac{1}{3}, \frac{1}{5}, \frac{1}{7}, \dots$  = amplitude of these frequencies

As you can see, the proportion of each higher frequency component gets smaller and smaller, and there comes a point where the addition of the next component makes little practical difference to the quality of the square wave for normal purposes. However, at least five components will be needed to guarantee a good waveform. The fifth component is  $9f$ , so here is the bottom line: if you want to look at square waves on your scope in terms of their shape, it must have a -3dB bandwidth at least 10 times the fundamental frequency of your square wave. In the real world, with practice, you can get away with about half this as a minimum ( $5f$ ), which is good news for the piggy bank, but extreme caution must be exercised when deciding which wobble is real and which is caused by the scope (artefact). Your cheap 20MHz (-3dB) scope can therefore be used reliably for up to 2MHz square waves, and with caution to 4MHz, but certainly not at higher frequencies unless you don't care about the shape of the displayed waveform.

## Spectrum Analysers

That covers my preliminary comments on real-time instruments, except for one: the spectrum analyser. So far, all our instruments have drawn graphs with voltage as one axis and time or voltage as the other. The spectrum analyser draws a slightly different kind of graph: one axis represents power and the other, frequency. The purpose of the spectrum analyser is to break down complex waveforms into their component sinusoids. We could, for example, have determined how imperfect our square wave was by using the spectrum analyser. The basic real-time instrument (Fig. 3) consists of a set of very precise band-pass filters, each of which is fed in parallel by the signal, and each of which feeds an integrator which delivers an output voltage proportional to the power at its input. The resultant voltages are displayed as a bar chart (or more rarely, as a curve) which shows the relative amplitude of each frequency component present. It is however, much cheaper (if quite a lot slower) to produce the same result using maths on a recorded signal waveform. This is done using a mathematical function called the Fourier transform on digitised data.

## Digital Alternatives

The increasingly common alternative to real-time instruments is the use of digitisers and off-line analysis

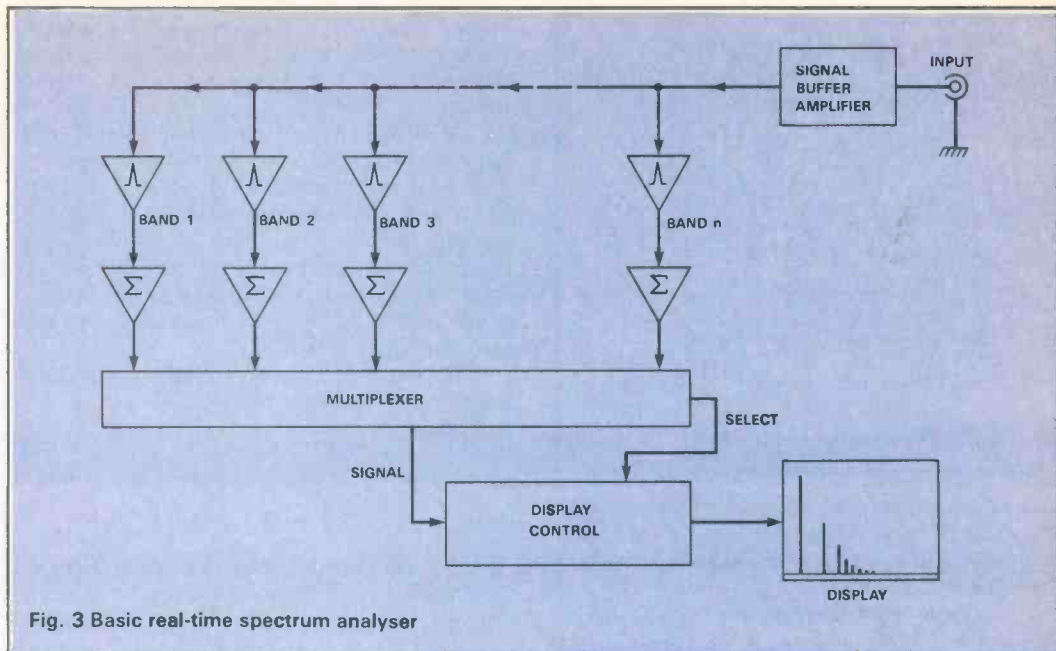


Fig. 3 Basic real-time spectrum analyser

tools (sadly, not called bogus-time instruments). The oscilloscope and spectrum analyser are not the only instruments to go digital. There is also a wide range of purely digital instrumentation such as bus analysers, logic analysers and so on, which are essentially digital and have no analogue counterparts.

Let us examine first the digital oscilloscope and spectrum analyser. The input to both devices is passed through an analogue to digital converter which converts the varying voltage input into a sequence of parallel binary words which can be stored in a conventional computer-type memory device.

From the user's point of view, these digital instruments are both functionally similar to their real-time counterparts. However, the digital approach has both advantages and limitations which are different from those of the analogue instruments. The major advantage is that the signal to be analysed is captured as digital information before anything else is done to it. The digital record may be stored permanently (on magnetic disk) and manipulated in a number of ways to allow any desired presentation of results. The distinction between the oscilloscope and the spectrum analyser, for example, ceases to be meaningful where you can afford a single digital instrument capable of presenting displays in both time domain and frequency domain from the same captured signal. Any manipulation of your signal which can be performed using electronic circuits can be simulated by suitable mathematical manipulation of the digitised signal data.

There is an important limitation which applies to

all digitisers. We have discussed the assumption that any waveform can be considered as the sum of a set of sinusoids. If you want to digitise a signal, you have to take samples of it at some constant rate. The faster you sample compared to the signal frequency, the more detail you record and the slower you sample, the less detail. As you sample slower and slower, there comes a point where you can no longer reconstruct the original waveform from the data you captured.

Looking at Fig. 4a, the signal is a pure sinusoid, and we are sampling at the same frequency as the signal. All we can reconstruct with certainty from the digitised data is a straight line; the signal has disappeared! Obviously we must sample at a faster rate. Let's try twice the frequency ( $2f$ ). Figures 4b and 4e show the result.

If we are unlucky enough to sample at exactly the zero crossings of the signal, we get nothing out just as before (Fig. 4b). However, when we start sampling at some point on the waveform which is not a zero-crossing the reconstructed waveform is correct in frequency but reduced in amplitude (Fig. 4c). Indeed, we would have to be lucky enough to sample exactly at the positive and negative peaks of the waveform (4d) to ensure that both frequency and amplitude are correctly recorded. If we had chosen a sampling rate of less than  $f$ , things would have been much worse (Fig. 4e). In this case, the amplitude information would not necessarily be lost, but the recovered frequency would have come out wrong. In fact, any component with a frequency greater than half the sample rate results in a false record at a lower frequency, called

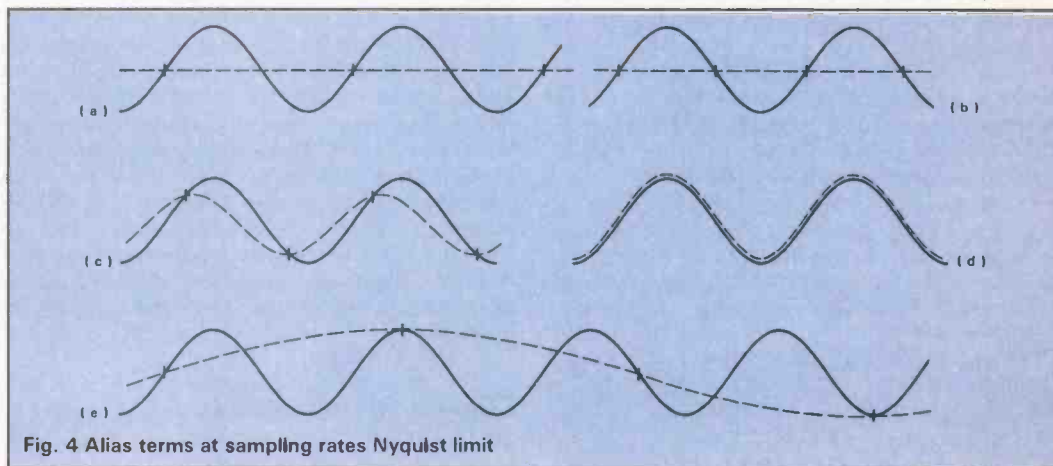


Fig. 4 Alias terms at sampling rates Nyquist limit

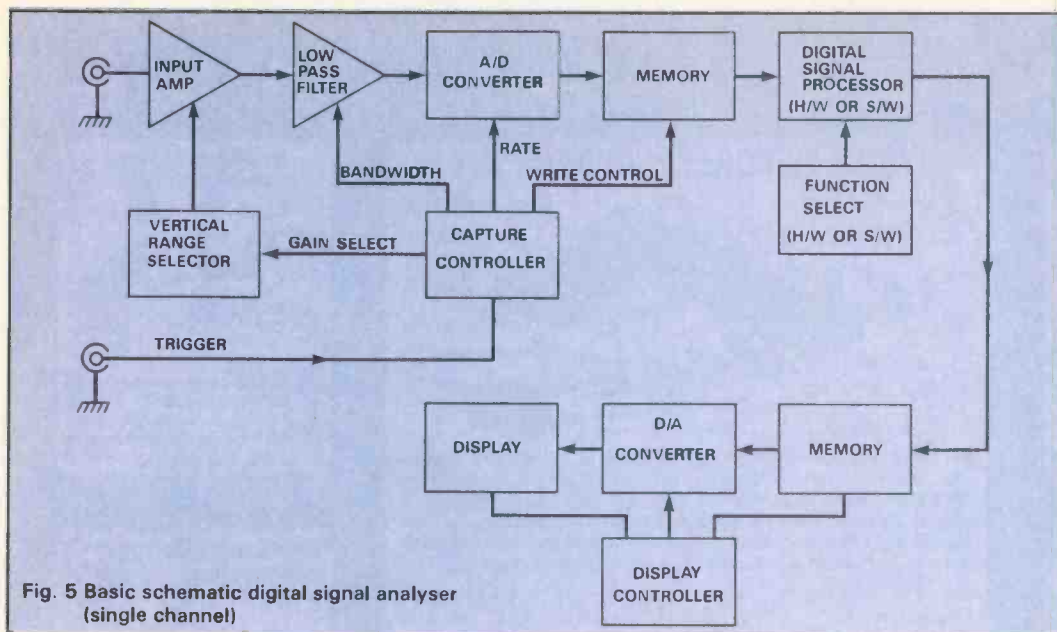


Fig. 5 Basic schematic digital signal analyser (single channel)

an alias term.

For reliable digital recording of the frequency of a sinusoid, we must sample at a frequency of  $2f$  or greater. This is referred to as the Nyquist limit and it applies to the highest frequency sinusoid present in any complex signal. You can calculate the frequency of an alias term by finding the difference between the real component and the Nyquist frequency of the digitiser, and then subtracting the difference from the Nyquist frequency. If we sample at 100kHz, the Nyquist frequency is 50kHz. A signal component at 70kHz will then produce an alias term of (50-20)kHz, or 30kHz. It follows that we can no longer push our instrumentation to its maximum limits as we could when using the analogue or real-time scope. In fact, as most complex signals have a very high real bandwidth, it is standard practice to include in digital test gear a low pass filter at the input. This ensures that no signal component which would violate the Nyquist limit is allowed to reach the digitiser. The reduction in accuracy resulting from the removal of the higher frequency components of the waveform is not such a problem as the distortion which would be caused by the presence of the low frequency alias terms if the low-pass filter was not used.

The major drawback of digital analysis equipment is price. Currently, fast A/D converters are very expensive. The digital equivalent of a 20MHz analogue (real-time) scope (a very basic cheap scope) would require at least a 50MHz A/D converter. This is quite a costly component (£30-40), but a decent professional's instrument of 60MHz bandwidth or thereabouts requires a 150MHz A/D which would set you back about £250 at present. Remember also, that the scope needs one A/D per channel, so the A/D converter bill for a digital version of my 60MHz scope would be about the same as the total bill for the analogue version. Fast devices get cheaper all the time, but so do test gear bandwidth expectations, so the overall situation stays much the same.

## Displaying Your Data

Having digitised your signal at the required rate, what do you do with the string of numbers you've got? The answer is: all sorts of things. Once you have your data stored permanently (or semi-permanently), you can do an enormous variety of manipulations on it. The data can be used to create a conventional voltage/time graph, a Fourier transform can be applied to it to generate a frequency/power graph, you can

digitally filter it to remove some frequency components, rescale any part of it, compare the digital records of two signals ... the list is endless. This is the major power of digital instrumentation, and it is effectively impossible to perform such a range of manipulations using real-time gear.

There are two alternative approaches to digital instruments with screen displays. They are vector plotting and raster scanning. Vector plotting produces the kind of screen image you get on a real-time scope. The trace is drawn as a continuous line from start to finish. However, as your data are samples separated by finite (short) time intervals, you would just get a string of dots if you used your data in its basic form. Vector plotting displays therefore, use quite horrendously complex *predictive drawing algorithms* (PDA): a load of maths is done on the data before displaying to allow your gear to join up the dots. It is not enough to just use straight lines: if you remember those kiddies' draw by numbers books, the pictures looked awful. The PDA works out the optimum curve needed to join the dots smoothly. These systems are expensive.

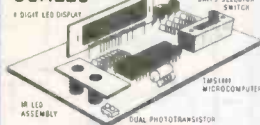
The raster scan approach is that used on your TV and computer screen. No attempt is made to join up the dots. They are just presented on the screen. Cheaper systems use this method, as does an increasing range of virtual test gear — little (or big) boards that plug inside your personal computer. Although the screen image is not so pretty, it is generally just as reliable as the vector graphic system with PDA.

Figure 5 shows the internals of a general digital scope-type instrument. A final point to note about signal processing is that whereas up to now, *software* has been used to perform data manipulation, new departures in hardware *digital signal processors* (microprocessors optimised for the mathematics associated with digitised signals) are becoming commonplace. Software is slow by comparison, and is ceasing to be cheaper day by day. It is now possible to hard wire a chip to perform in sub-millisecond timescales a data manipulation that could take ten seconds using conventional software on your micro-computer. DSP devices are therefore likely to take over the whole range of precision digital instrumentation in the very near future, with the possible exception of the low end of the educational (toy computer) market.

Next month we will look at signal sources, which are used to provide the known values (constants) in experiments, and at precision backups to scopes such as frequency meters, power meters and the like.

# TK FOR KITS

## ELECTRONIC WEIGHING SCALES



Kit contains a single chip micro-processor, PCB displays and all electronics to produce a digital LED readout of weight in Kgs or Sts/lbs. A PCB link selects the scale—bathroom/ two types of kitchen scales. A low cost digital ruler could also be made.

ES1 ..... £7.20

## BEGINNERS KITS



These kits are simple to build even for the complete novice. Kits include ALL components, printed circuit and full instructions and are powered by a 9v battery (not supplied).

**SK1 DOORCHIME** — plays 'For Alice' when button is pressed ..... £3.90

**SK2 WHISTLE SWITCH** — switches a relay on and off in response to a whistle. Switch your TV or radio on and off by whistling ..... £3.90

**SK3 SOUND GENERATOR** — police, ambulance/fire engine siren plus machine gun sounds available at the touch of a switch. Just right for you BMX bike ..... £3.90

**XK113 MW RADIO** — based on the ZN414 chip, builds into a super little radio with built in ferrite aerial and earpiece for personal listening ..... £6.60

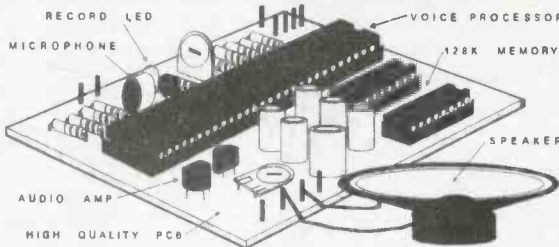
**XK118 TEN EXCITING PROJECTS FOR BEGINNERS.** This kit contains a solderless breadboard, components and a booklet with instructions to enable the absolute novice to build ten fascinating projects, including a light operated switch, intercom, burglar alarm and electronic lock. Each project includes a circuit diagram, description of operation and an easy to follow layout diagram. A section on component identification and function is included, enabling the beginner to build the circuits with confidence ..... £15.00

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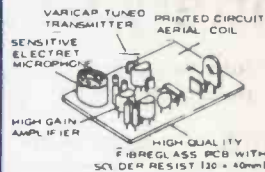


This simple to construct and even simpler to operate kit will record and playback short messages or tunes. It has many uses — seatbelt or lights reminder in the car, welcome messages to visitors at home or at work, warning messages in factories and public places, in fact anywhere where a spoken message is announced and which needs to be changed from time to time. Also suitable for toys — why not convert your daughter's £8 doll to an £80 talking doll!!

Size ..... 78x60x15 mm  
Message time ..... 1-5 secs normal speed, 2-10 secs slow speed

XK129 ..... £22.50

## SUPER-SENSITIVE MICROBUG KIT



Only 45x25x15mm, including built-in mic. 88-100MHz (standard FM radio). Range approx. 300m depending on terrain. Powered by 9V PP3 (7mA). Ideal for surveillance, baby alarm etc. .... £5.50

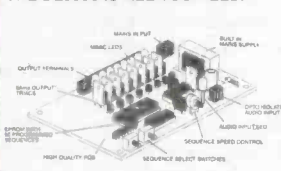
## VERSATILE REMOTE CONTROL KIT



Includes all components (+transformer) for a sensitive IR receiver with 16 logic outputs (0-15V) which with suitable interface circuitry (relays, triacs, etc — details supplied) can switch up to 16 items of equipment on or off remotely. Outputs may be latched to the last received code or momentary (on during transmission) by specifying the decoder IC and a 15V stabilised supply is available to power external circuits. Supply: 240V AC or 15-24V DC at 10mA. Size (exc transformer) 9x4x2 cms. Companion transmitter is the MK18 which operates from a 9V PP3 battery and gives a range of up to 60ft. Two keyboards are available — MK9 (4-way) and MK10 (16-way).  
MK12 IR Receiver (inc transformer) ..... £17.00  
MK18 Transmitter ..... £7.80  
MK9 4-way Keyboard ..... £2.40  
MK10 16-way Keyboard ..... £7.00  
601133 Box for Transmitter ..... £2.60

## DISCO LIGHTING KITS

DON'T CHASE AROUND FOR A LIGHT SEQUENCER FOR YOUR DISCO — THE DL8000 IS ALL YOU NEED.



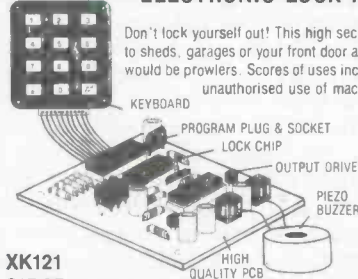
The DL8000K is an 8-way sequencer kit complete with an EPROM containing EIGHTY — YES! 80! different flashing and chasing patterns which can be selected by means of two selector switches. The speed of the sequence can be controlled by a potentiometer or from the built in opto isolated audio input and each output triac can switch 300W of mains lighting (up to 1KW if heatsinks are fitted). Zero voltage switching is used to minimise interference with audio equipment and 8 mimic LEDs are included. The kit is supplied with full instructions, mains transformers, PCB, switches and electronic components — even the PCB connectors. The size is 130x85x35mm and the price is ..... ONLY £34.60

## XK124 POWER STROBE KIT



Designed to produce intense light pulses in the variable frequency of 1-15Hz this kit also includes circuitry to trigger the light from an external voltage source (eg. audio amplifier) via an opto isolator, making it ideal for disco use. Instructions are also supplied to modify the unit for manual triggering via a push button or as a slave flash in photographic applications. The unit operates directly from the 240v mains supply although for portable applications a simple inverter could be used. Order as XK124 ..... £15.00  
DL1000K A value for money 4-way CHASER kit featuring bidirectional sequence and dimming. 1KW/channel ..... £21.00  
DL21000K A lower cost CHASER with zero voltage switching and unidirectional sequence. .... £11.80  
DLA1 (for DL/DL21000K) Optional OPTO INPUT allowing for audio 'beat' light response. .... £8.00  
DL3000K A 3-channel SOUND-TO-LIGHT featuring zero voltage switching, auto level control, built-in microphone and 1KW/channel. Bass, mid and treble outputs. .... £17.00

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XK114 Relay kit for CT6000 includes PCB, connectors and one relay. Will accept up to 4 relays. 3A/240V c/o contacts ..... £4.75  
701115 Additional relays ..... £1.80

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# TECH TIPS

# READERS CIRCUITS

## Battery Charger Alert

A. H. Robson  
Northumberland

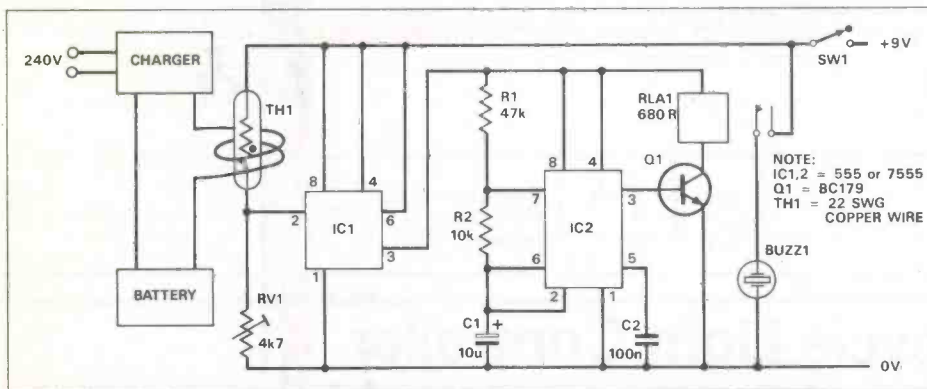
**T**he purpose of this circuit is to give a warning signal when a battery under charge is replenished. During charging, the current is at first high but drops with time. By inserting a short length of copper wire in one of the leads and coiling it round a thermistor, the drop in temperature to a certain level will signal that charging is complete.

Seven turns of 22 gauge enamelled copper wire are wound round the thermistor, the latter having a resistance of about 5k3 at 20°C. The thermistor is connected to one arm of a 555 IC potential divider circuit with a balancing preset resistor in the other.

When activated, this circuit triggers an oscillator to give an intermittent buzzer alarm.

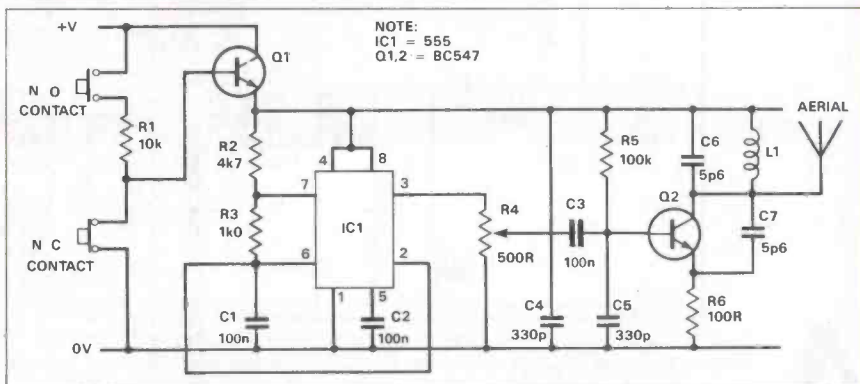
With a partly exhausted battery connected to the charger, adjust the preset to give zero output. When the charger ammeter indicates that charging is nearly complete, or bubbles start to rise in the electrolyte, adjust the preset again to just trigger the alarm. The device is now set.

A single probe single throw reed relay is suitable for this circuit. 7555 ICs may be substituted for the 555s at greater initial cost, but they will consume less power.



## A Radio Transmitter Alarm

Paul Benton  
Staffordshire



**T**he radio transmitter alarm was originally designed for a company who wanted to monitor an area that they believed to be in danger of receiving 'unwanted visitors'. They had been suffering a loss of stock that, in terms of nuisance value, was costing the company considerable time and effort.

The requirements were the alarm would be silent and that the security personnel could monitor the illegal entry at a distance of 400 metres. This meant that with no apparent security in the vicinity, the pilfering would take place but security would know of this activity. The thieves could then be caught red-handed as soon as they left the building. A further requirement was ease of fitting the alarm, since the security guards did not wish to wire up a complicated system (an activity which would have pre-warned

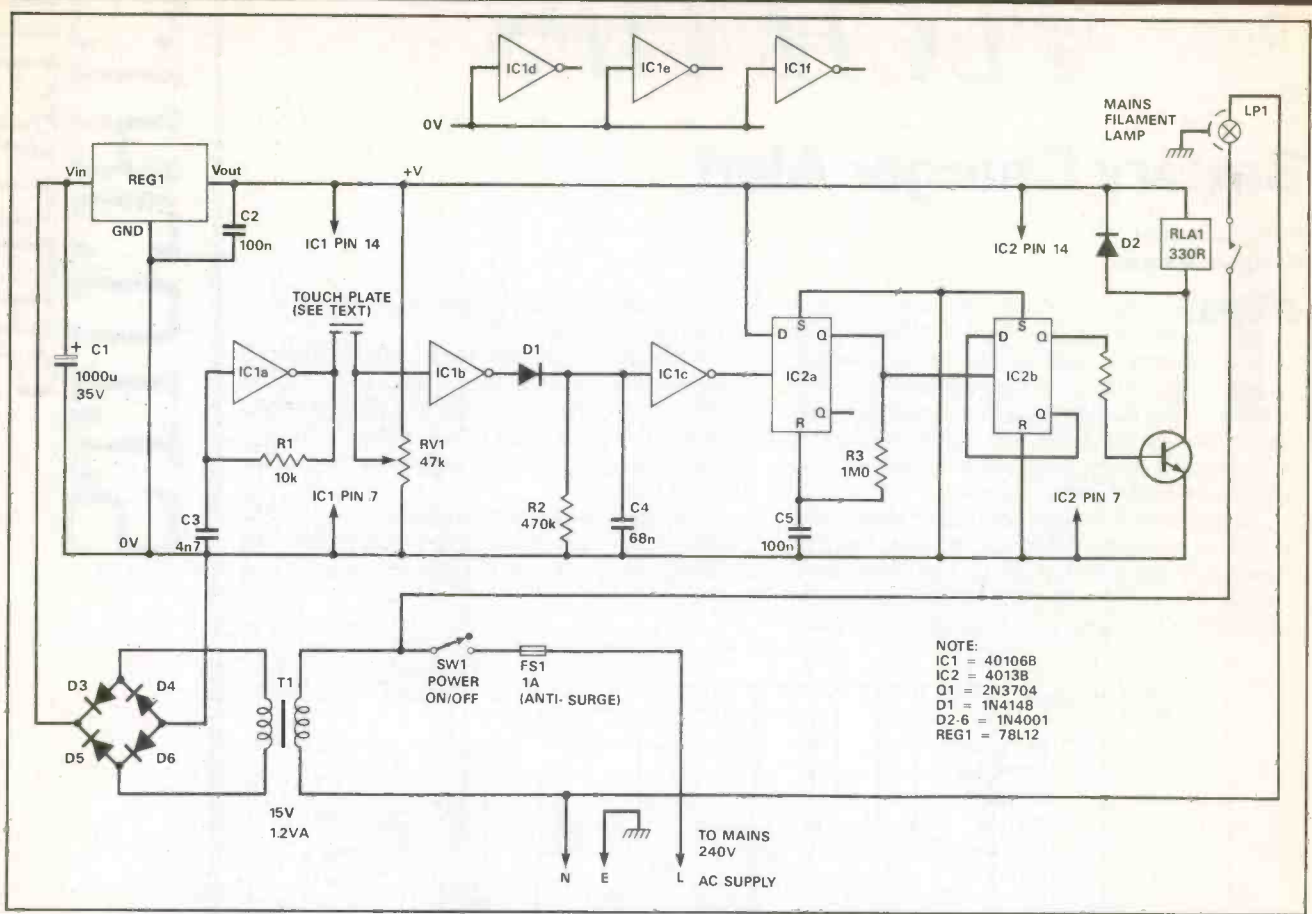
members of the offending team).

The circuit can be constructed on stripboard, all components being readily available. Once the approximate centre frequency is found, the frequency may be altered by gently stretching or compressing coil L.

The range of the transmitter will vary on length and positioning of aerial, terrain, receiver quality and battery. Range will be typically 1/2 mile.

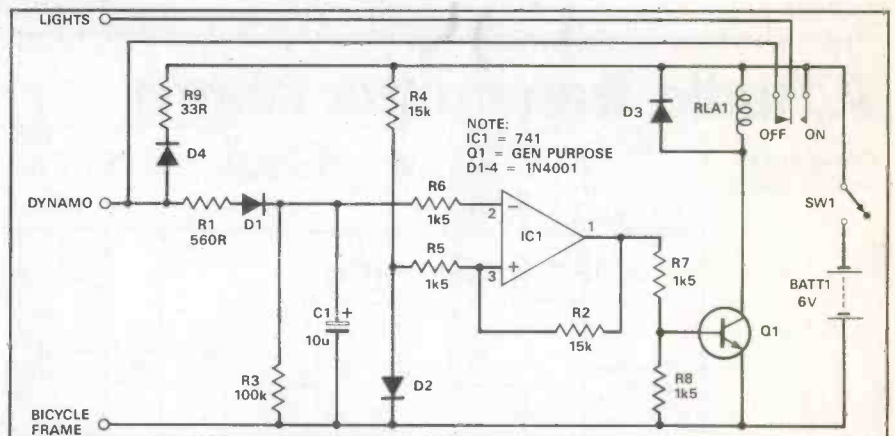
The variable resistor R4 enables the user to adjust the amount of modulation to the transmitter. Greater modulation will increase the apparent range, but will give rise to an RF signal much richer in spuriae

*Note that it is illegal to operate or install any radio transmitter without obtaining a licence from the DTI (UK).*



## Bicycle Light Controller

Gordon  
Blackwell  
West Germany



A dynamo is a convenient, cheap and 'always available' source of power for bicycle lights, but suffers from the drawback that when the bike is stationary, there are no lights. Batteries on the other hand provide a continuous light output, but need replacing frequently.

The circuit described combines the advantages of both by switching the lights to the dynamo when its output is high enough, and to batteries when the dynamo output falls below a preset limit, for instance while stationary at a junction. In this way, battery life is greatly extended, and the dynamo's drawback of 'no motion no light' is overcome.

There are many ways to achieve the action described. The present circuit uses a 741 IC as voltage comparator, driving a relay via a power boosting transistor. Although circuits using diodes, thyristors, or transistors as switches are conceivable, a relay circuit was chosen for this application to avoid voltage losses

in the low voltage (6V) system, which would reduce light brightness. The current drain of the relay is small compared with that of the lights.

As a safety feature, if either batteries or circuit should fail, or the unit is turned off, the lights operate as normal from the dynamo, but if the dynamo fails or is turned off, the lights run directly from the batteries. The circuit therefore also acts as a lighting backup system.

In action, the dynamo output is rectified and smoothed by D1 and C1, and the voltage compared with a reference provided by D2. Sensitivity can be adjusted if necessary with R1, while the positive feedback resistor R2 introduces hysteresis into the circuit to prevent relay judder. Other components are conventional.

Although 6V is too low for a 741 IC, no problems have been experienced in practice. An alternative would be to use a pin compatible low voltage IC namely the 251 at slightly greater cost.

# Touch Activated Light Switch

Terry Grice  
Tyne and Wear

**T**his circuit was designed to allow a bedside lamp to be controlled through successive operation of a touch sensitive pad, an arrangement which could benefit the elderly or infirm. The use of a suitable mains switching relay along with a mains transformer of split bobbin design ensures that total electrical isolation exists between the user and the mains supply.

Circuit operation is as follows. The output from the secondary winding of the mains step-down transformer T1 is full-wave rectified by diodes D3 to D6 and smoothed by C1, voltage stabilisation necessary for reliable circuit operation is provided by positive voltage regulator REG1. The square-wave output signal generated by the 15kHz oscillator formed by IC1a, R1 and C3 is fed via the capacitive touch plate to the input of buffer IC1b. The inverted output rapidly pump charges C4 to a logic 1 level via D1. This results in a steady logic 0 level at the output of IC1c. When finger contact is made with the touch pad, the oscillator output is heavily attenuated. The DC voltage present on the slider (RV1) holds the input of IC1b high. The inverted output allows C4 to discharge through R2. At the instant IC1c input reverts to a logic 0, a positive-going transition is produced at the output, triggering the clock input of the monostable multivibrator. This is formed by a D type flip-flop IC2a and timing components R3 and C5.

This arrangement is included to prevent erratic circuit operation which might otherwise occur when the operator's hand is in close proximity to the touch plate. The leading edge of the 100ms positive-going pulse produced at the Q output strobes the clock input of IC2b. As this second D type flip-flop is configured as a divide-by-two circuit, the Q output toggles between logic states with successive operations of the touch plate. When high, the output sources current to the base of Q1 through a current limiting resistor R4, saturating the transistor and energising the coil of RLA1. D2 is included to protect Q1 from any back emf generated by the coil of RLA1. When the normally open relay contacts close, mains power is delivered to LP1, a suitably rated mains filament lamp. Care should be taken to ensure that SW1, FS1 and the relay contacts are wired into the live side of the transformer primary circuit. If a metal lampholder and/or the case used to house the circuitry is of metal construction, the necessary connections to the mains protective earth terminal must be provided.

Finally, a touch plate may be manufactured using double-sided copper clad board. Keeping the upper surface intact, the lower surface is split into two equal lands by removing a strip of copper approximately 2mm wide. Plate area should be conducive to the user's requirements, 25cm<sup>2</sup> being typical, but the precise dimensions are not critical.

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6JS6C	9.50	5881	9.95	E88CC	3.50	KT67	9.00
6KD6	10.50	5899	4.50	E88CC01	6.95	KT77	15.00
6L6GC	3.50	5963	1.75	E182CC	9.00	KT88	15.00
6LQ6	9.50	5965	2.15	E188CC	7.50	M8136	7.00
6SN7GT	1.95	6057	3.75	EC8010	12.00	M8137	7.95
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- BD11 1 6½" speaker cabinet ideal for extensions, takes your speaker. Ref BD137 + 50p.
- BD13 12 30 watt reed switches, it's surprising what you can make with these — burglar alarms, secret switches, relay etc. etc.
- BD22 2 25 watt loud speaker two unit cross-overs
- BD29 1 B.O.A.C. stereo unit is wonderful breakdown value
- BD30 2 nicad constant current charges adapt to charge almost any nicad battery
- BD32 2 humidity switches, as the air becomes damper the membrane stretches and operates a microswitch
- BD42 5 13A rocker switch three tag so on/off, or change over with centre off
- BD45 1 24hr time switch, ex-Electricity Board, automatically adjust for lengthening and shortening day
- BD49 5 neon valves, with series resistors, these make good night lights
- BD56 1 mini uniselector, one use is for an electric jigsaw puzzle, we give circuit diagram for this. One pulse into motor, moves switch through on pole
- BD59 2 flat solenoids — you could make your multi-tester read AC amps with this
- BD67 1 suck or blow operated pressure switch, or it can be operated by any low pressure variations such as water level in water tanks
- BD103A 1 6v 750mA power supply, nicely cased with input and output leads
- BD120 2 stripper boards each contains a 400v 2A bridge rectifier and 14 other diodes and rectifiers as well as dozens of condensers etc
- BD126 10 very fine drills for p.c.b. boards etc. Normal cost about 80p each
- BD132 2 plastic boxes approx. 3" cube with square hole through top so ideal for interrupted beam switch
- BD134 10 motors for model aeroplanes, spin to start so needs no switch
- BD139 6 microphone inserts — magnetic 490 ohm also act as speakers
- BD149 4 reed relay kits you get 16 reed switches and 4 coil sets with notes on making c/o relays and other gadgets
- BD149 6 safety cover for 13A sockets — prevent those inquisitive little fingers getting nasty shocks
- BD180 6 neon indicators in panel mounting holders with lens
- BD193 6 5amp 3 pin flush mounting sockets makes a low cost disco panel — need cable clips
- BD196 1 in flex simmerstat — keeps your soldering iron etc always at the ready
- BD199 1 mains solenoid very powerful has 1" pull or could push if modified
- BD201 8 keyboard switches — made for computers but have many other applications
- BD211 1 electric clock mains operated put this in a box and you need never be late
- BD221 5 12v alarms make a noise about as loud as a car horn. Slightly solid but OK
- BD242 2 6" x 4" speakers 4 ohm made from Radiomobile so very good quality
- BD252 1 panostat, controls output of boiling ring from simmer to boil
- BD259 50 leads with push on ¼" tags — a must for hook ups — mains connections etc
- BD263 2 oblong push switches for bell or chimes, these can mains up to 5 amps so could be foot switch if fitted into pattress mini 1 watt amp for record player. Will also change speed of record player motor
- BD283 3 mild steel boxes approximately 3" x 3" x 1" deep — standard electrical
- BD293 50 silicon diodes
- BD305 1 tubular dynamic mic with optional table rest
- BD667 2 4.7uf, non-polarised block capacitors, pcb mounting
- BD400 4 Books. Useful for beginners. Describes amplifiers, test equipment and kit sets
- BD653 2 Miniature driver transformers. Ref LT44. 20k to 1k, centre tapped
- BD553a 2 3.5 volt operated relays, each with two pairs CO contacts

There are over 1,000 items in our Bakers Dozen List. If you want a complete copy please request this when ordering.

**EQUIPMENT WALL MOUNT** It is a multi-adjustable metal bracket that could be used for mounting flood light, loudspeaker, TV camera, even a fan and on almost any sort of wall or ceiling even between wall and ceiling. The main fixing brackets rotate such that an inward or outward corner can be accommodated. Front panel also tilts upward or downwards to a reasonable angle and can be easily removed separately for wiring. A very useful bracket. Regular price would be around £6 each. Our price only £3. Our ref 3P72. or 2 for £5. Our ref 5P152.

**EXTRA SPECIAL CROC CLIPS** Medium size, just right for most hook-ups. Normally sell for around 10p to 15p each. These are insulated and have a length of wire connected to them but this is very easy to snip off if you do not need it. 20 for £1. Our ref BD117A.

**COPPER CLAD PANEL** For making PCB. Size approx 12in long x 8½in wide. Double-sided on fibreglass middle which is quite thick (about 1/16in) so this would support quite heavy components and could even form a chassis to hold a mains transformer, etc. Price £1 each. Our ref BD833.

**FET CAPACITOR MICROPHONE EAGLE CI.200** Output equivalent to a high class dynamic microphone while retaining the characteristics of a capacitor microphone. Price £1. Our ref BD646.

**SUB-MIN TOGGLE SWITCH.** Body size 8mm x 4mm x 7mm SBDT with chrome dolly fixing nuts. 3 for £1.00. Order ref BD649.

### POWERFUL IONISER

Generates approx. 10 times more IONS than the ETI and similar circuits. Will refresh your home, office, workshop etc. Makes you feel better and work harder — a complete mains operated kit, case included. £12.50 + £2 P&P. Our ref 12P51.

**REAL POWER AMPLIFIER** for your car, it has 150 watts output. Frequency response 20hz to 20Khz and signal to noise ratio better than 60db. Has built in short circuit protection and adjustable input level to suit your existing car stereo, so needs no pre-amp. Works into speakers ref. 30P7 described below. A real bargain at only £57.50. Order ref: 57P1.

**REAL POWER CAR SPEAKERS.** Stereo pair output 100w each. 4-Ohm impedance and consisting of 6½" woofer, 2" mid range and 1" tweeter. Each set in a compact purpose built shelf mounting unit. Ideal to work with the amplifier described above. Price per pair £2996. Order ref: 30P7.

**STEREO CAR SPEAKERS.** Not quite so powerful — 70w per channel. 3" woofer, 2" mid range and 1" tweeter. Again, in a super purpose built shelf mounting unit. Price per pair: £2795. Order ref: 28P1.



**12" HIGH RESOLUTION MONITOR.** Black and white screen, beautifully cased for free standing, needs only a 12v 1.5 amp supply. Technical data is on its way but we understand these are TTL input. Brand new in maker's cartons. Price: £25.00. Free delivery. Order ref 28P1.

**14" COLOUR MONITOR** made by the American Display Tek company. Uses high resolution tube made by the famous Japanese Toshiba company. Beautifully made unit intended for console mounting, but top and sides adequately covered by plated metal panels. Full technical spec. on its way to us. We have limited number of these. All brand new still in maker's cartons. Price £89 each plus £6 insured carriage. Order ref 89P1.

**BUSH RADIO MIDI SPEAKERS.** Stereo pair. BASS reflex system, using a full range 4in driver of 4 ohms impedance. Mounted in very nicely made black fronted walnut finish cabinets. Cabinet size approx 8½in wide, 14in high and 3½in deep. Fitted with a good length of speaker flex and terminating with a normal audio plug. Price £5 the pair plus £1 post. Our ref 5P141.

**3½in FLOPPY DRIVES.** We still have two models in stock: Single sided, 80 track, by Chicon. This is in the manufacturers metal case with leads and IDC connectors. Price £40, reference 40P1. Also a double sided, 80 track, by NEC. This is uncased. Price £59.50, reference 60P2. Both are brand new. Insured delivery £3 on each or both.

**ATARI 65XE COMPUTER.** At 64K this is most powerful and suitable for home and business. Brand new, complete with PSU, TV lead, owner's manual and six games. Can be yours for only £45 plus £3 insured delivery.



**REMOTE CONTROL FOR YOUR 65XE COMPUTER.** With this outfit you can be as much as 20 feet away as you will have a joystick that can transmit and receive to plug into and operate your computer and TV. This is also just right if you want to use it with a big screen TV. The joystick has two fire buttons and is of a really superior quality, with four suction cups for additional control and one handed play. Price £15 for the radio controlled pair. Our ref 15P27.

**65XE COMPENDIUM.** Contains: 65XE Computer, its data recorder XC12 and its joystick with 10 games. Price £62.50 + £4 Insurance Delivery.

**ASTEC PSU.** Mains operated switch mode, so very compact. Outputs: +12v 2.5A, +5v 6A, ±5v 5A, ±12v 5A. Size: 7¼in long x 4¾in wide x 2¾in high. Cased ready for use. Brand new. Normal price £30 +, our price only £12.95. Our ref 13P2.

**VERY POWERFUL 12 VOLT MOTORS.** 1/3rd Horsepower. Made to drive the Sinclair C5 electric car but adaptable to power a go-kart, a mower, a rail car, model railway, etc. Brand new. Price £20 plus £2 postage. Our ref 20P22.

### PHILIPS LASER

This is helium-neon and has a power rating of 2mW. Completely safe so long as you do not look directly into the beam when eye damage could result. Brand new, full spec. £30 plus £3 insured delivery. Mains operated power supply for this tube gives 8kv striking and 1.25kv at 5mA running. Complete kit with case £15. As above for 12v battery. Also £15. Our ref 15P22.

**ATARI 65XE COMPENDIUM** includes 65XE, PSU, 10 games, leads, joystick and data recorder £62.50 plus £4.00 insured delivery. Our ref 62P15.

**FULL RANGE OF COMPONENTS** at very keen prices are available from our associate company SCS COMPONENTS. You may already have their catalogue, if not request one and we will send it FOC with your goods.

**HIGH RESOLUTION MONITOR.** 9in black and white, used Philips tube M24/306W. Made up in a lacquered frame and has open side. Made for use with OPD computer but suitable for most others. Brand new, £16 plus £5 post. Our reference 16P1.

**12 VOLT BRUSHLESS FAN.** Japanese made. The popular square shape 4¼in x 4¼in x 1¼in. The electronically run fans not only consume very little current but also they do not cause interference as the brush type motors do. Ideal for cooling computers, etc., or for a caravan. £8 each. Our ref 8P26.

**MINI MONO AMP** on p.c.b. size 4" x 2" (app.) Fitted Volume control and a hole for a tone control should you require it. The amplifier has three transistors and we estimate the output to be 3W rms. More technical data will be included with the amp. Brand new, perfect condition, offered at the very low price of £1.15 each, or 13 for £12.00.



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**POPULAR ITEMS — MANY NEW THIS MONTH** JOYSTICKS for BBC, Atari, Dragon, Commodore, etc. All £5 each. All brand new, state which required.

**TELEPHONE TYPE KEY PAD.** Really first class rear mounting unit. While lettering on black buttons. Has conductive rubber contacts with soft click operation. Circuit arranged in telephone type array. Requires 70mm by 55mm cutout and has a 10 IDC connector. Price £2.00. Ref 2P251.

**SUB-MIN PUSH SWITCHES** Not much bigger than a plastic transistor but double pole. PCB mounting. Three for £1. Our ref BD688.

**AA CELLS.** Probably the most popular of the rechargeable NICAD types. 4 for £4. Our ref 4P44.

**20 WATT 40HM SPEAKER** With built in tweeter. Really well made unit which has the power and the quality for hi-fi. 6½in dia. Price £5. Our ref 5P155 or 10 for £40 ref 40P7.

**MINI RADIO MODULE** Only 2in square with ferrite aerial and solid dia tuner with own knob. It is a superhet and operates from a PP3 battery and would drive a crystal headphone. Price £1. Our ref BD716.

**BULGIN MAINS PLUG AND SOCKET.** The old faithful 3 pin with screw terminals. The plug is panel mounted and the socket is cable mounted. 2 pairs for £1 or 4 plugs or 4 sockets for £1. Our ref BD715, BD715P or BD715S.

**MICROPHONE.** Low cost hand held microphone with on/off switch in handle, lead terminates in one 3.5 plug and one 2.5 plug. Only £1. Ref BD711.

**MOSFETS FOR POWER AMPLIFIERS AND HIGH CURRENT DEVICES** 140v 100w pair made by Hitachi. Ref 25K413 and its component 25J118. Only £4 a pair. Our ref 4P42. Also available in H pack Ref 25J99 and 25K343 £4 a pair. Ref 4P51.

**TIME AND TEMPERATURE LCD MODULE.** A 12 hour clock, a Celsius and Fahrenheit thermometer, a too hot alarm and a too cold alarm. Approx 50 x 20mm with 12.7mm digits. Requires one AA battery and a few switches. Comes complete with full data and diagram. Price £6. Our ref 6P12.

**REMOTE TEMPERATURE PROBE FOR ABOVE.** £3. Our ref 3P60.

**A REAL AIR MOVER.** Circular axial fan moves 205 cubic foot per min which is about twice as much as our standard 4½in fans. Low noise mains operated 6½in dia, brand new. Regular price over £30, our price only £10. Our ref 10P71.

**600 WATT AIR OR LIQUID MAINS HEATER.** Small coil heater made for heating air or liquids. Will not corrode, lasts for years, coil size 3in x 2in mounted on a metal plate for easy fixing, 4in dia. Price £3. Ref 3P78 or 4 for £10. Our ref 10P76.

**EX EQUIPMENT SWITCHED MODE POWER SUPPLIES.** Various makes and specs but generally ±5, ±12v, ideal bench supply. Only £8. Our ref 8P36.

**ACORN DATA RECORDER.** Made for Electron or BBC computer but suitable for others. Includes mains adaptor, leads and book. £12. Ref 12P15.

**PTFE COATED SILVER PLATED CABLE.** 19 strands of 2mm copper, will carry up to 30A and is virtually indestructible. Available in red or black. Regular price is over £120 per reel, our price only £20 for 100m reel. Ref 20P21 or 1 of each for £35. Ref 35P2. Makes absolutely superb speaker cable!

**NEW PIR SENSORS.** Infra red movement sensors will switch up to 500w mains. UK made. 12 months manufacturers warranty. 15-20m range with a 0-10min timer, adjustable wall bracket. Only £2. Ref 20P24.

**MITSUBISHI 3½in DISC DRIVES.** Brand new drives, ½ height double sided, double density, warranted. Our price £60. Ref 60P5.

**10 MEMORY PUSHBUTTON TELEPHONES.** These are customer returns and "sold as seen" but are complete and generally need attention. Price £6. Ref 6P16 or 2 for £10. Ref 10P77. BT approved.

**DEHUMIDIFIERS.** Domestic mains powered dehumidifiers these are customer returns and sold as seen. Price £30. Our ref 30P9. Callers only please.

**SPECTRUM PRINTER INTERFACE.** Add a centronics interface to your Spectrum complete with printer cable for only £4. Our ref 4P52.

**SPECTRUM SOUND BOX.** Add sound to your Spectrum with this device; just plug in. Complete with speaker, volume control and nicely boxed. A snip at only £4. Our ref 4P53.

**BBC JOYSTICK INTERFACE.** Converts a BBC joystick port to an Atari type port. Price £2. Our ref 2P261.

**TELEPHONE EXTENSION LEAD.** 5M phone extension lead with plug on one end and socket on the other. White. Price £3. Our ref 3P70 or 10 leads for only £19! Ref 19P2.

**LCD DISPLAY.** 4½in digits supplied with connection data £3. Ref 3P77 or 5 for £10 Ref 10P78.

**CROSS OVER NETWORK.** 8 ohm 3-way for tweeter midrange and woofer. Nicely cased with connections marked. Only £2. Our ref 2P255 or 10 for £15 ref 15P32.

**REFERRING LIGHT ALARM.** Fits to car reversing light and sounds when reversing. Only £2. Our ref 2P248.

**BASE STATION MICROPHONE.** Top quality uni-directional electret condenser mic 600r impedance sensitivity 16-18KHz — 68db built in chime, complete with mic stand bracket. £15. Ref 15P28.

**MICROPHONE STAND.** Very heavy chromed mic stand, magnetic base. 4in high. £3 if ordered with above mic. Our ref 3P80.

**SOLAR POWERED NI-CAD CHARGER.** 4 Nicad AA battery charger charges 4 batteries in 8 hours. Price £6. Our ref 6P3.

**MAINS SOLDERING IRON.** Price £3. Our ref 3P65.

**SOLDERING IRON STAND.** Price £3. Our ref 3P66.

**PIR SENSORS.** Suitable for alarm systems etc. Nicely boxed. Priced at only £10. Our ref 10P79.

**SHARP PLOTTER PRINTER.** New 4 colour printer originally intended for Sharp computers but may be adaptable for other machines. Complete with pens, paper, etc. Price £16. Our ref 16P3.

**CAR IONIZER KIT.** Improve the air in your car, clears smoke and helps prevent fatigue. Case req. Price £12. Our ref 12P8.

**NEW FM BUG KIT.** New design with PCB embedded coil 9v operation. Priced at £5. Our ref 5P158.

**NEW PANEL METERS.** 50UA movement with three different scales that are brought into view with a lever. Price only £3. Ref 3P81.

**STROBE LIGHTS.** Fit a standard Edison screw light fitting 240v 40/min flash rate, available in yellow, blue, green and red, complete with socket. Price £10 each. Ref 10P80 (state colour reqd).

**ELECTRIC SPEED CONTROL KIT.** Suitable for controlling our powerful 12v motors. Price £17. Ref 17P3 (heatsink required).

**EXTENSION CABLE WITH A DIFFERENCE.** It is flat on one side, making it easy to fix and look tidy. 4 core, suitable for alarms, phones etc. Our price only £5 for 50m reel. Ref 5P153.

**METAL PROJECT BOX.** Ideal for battery charger, power supply etc., sprayed grey, size 8" x 4" x 4½", louvred for ventilation. Price £3. Ref 3P75.



## LASER COMPETITION

Back, way back in the midst of time (the September issue to be precise), we had a stupendous competition to give away not only one of Maplin's coo-gosh lasers, fully built and ready to lase, but Maplin's controller unit to whizz it into a whirl to wow the world.

There were five questions, to which the answers are:

- 1C LASER is an acronym for Light Amplification by Stimulated Emission of Radiation
- 2D One light year is approximately  $9.46073 \times 10^{14}$  mm (watch those units!)
- 3E Boron is not a gas used commonly in lasers — it isn't a gas at all (at rt)
- 4A 'Lasers are illegal in Norway' is of course complete rubbish — oddly this is the question most people got wrong . . .
- 5D Erm . . . whoops. A typographical slip meant that none of the answers were technically perfect — but D (800nm) is the nearest. Any entries marked 'I don't know', 'none of the above' or 'wharra cock-up' were allowed into the final draw.

The first prizewinner was Mr Richard Blundell of Rugby, who will receive his prize just as soon as we stop playing with it. He will also receive a complimentary pair of entry tickets to the London Laserium to witness the spectacular whizzbang shows therein. Runners-up were Mr G J Parker of New Southgate, London (Laserium tickets) and Mr R E Davis of Thornton Heath, Surrey (free year's subscription to ETI).

Commiserations to all those who entered but didn't get a thing, and our thanks to Maplin and the London Laserium.

# WINNERS

## THE GRAND ETI SUBSCRIPTIONS OFFER

In the September and October issues we ran a subscriptions offer with a competition to win Hart's kit for the John Linsley Hood's 80W Audio Design MOSFET Amplifier. The oh-so-tricky questions involved identifying obscure bits of past covers (an idea borrowed with best grace from early 70s issues of Family Circle). The answers were:

- A June issue (the piano stool)
- B July issue (Einstein)
- C May issue (bucket handle)
- D September issue (treasure coin)

The winner is Mr Daniel Bull from Milton Keynes, lucky thing, and he'll be receiving his prize as soon as we've been to the Post Office to buy the stamps.

## ROCK CIRCUS COMPETITION

Gosh golly surely not another competition you missed? Yes in our prize-winning November issue, the Rock Circus feature was followed by a chance to win six pairs of ever-so-free tickets to see the audio animatronic marvels shake their things and strut their funky chickens and so forth.

- The answers were:
- 1. Dark side of the moon
  - 2. The white album
  - 3. Physical graffiti
  - 4. No jacket required

### 5. Venus and Mars

Again the entries literally jitterbugged in, and the six winners were: R. Gilchrist from Bristol, G S Symes of Lymington, M Wigley of Dorchester, Tim McKernan of Harpenden, R Hart of Putney and Phil Sturges of Maldon.

These people should already have received their prizes, and will no doubt soon be donning their portable headphones and watching the metal musos blowing their valves above the streets of Piccadilly Circus. More competitions follow soon!

# COMPETITION RESULTS

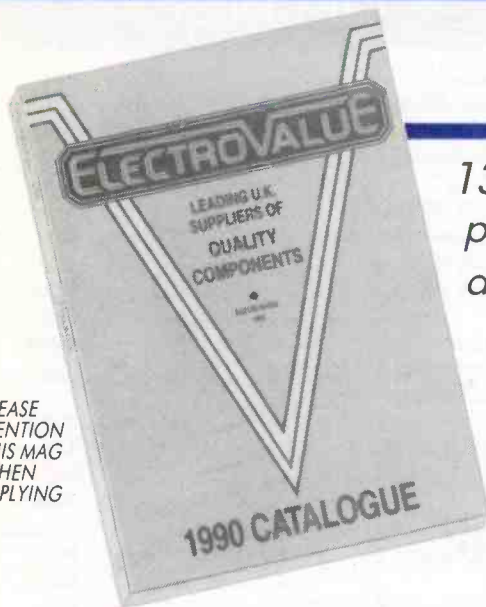
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# 1989 INDEX

SEE DECEMBER 1989 p34 FOR PROJECTS

## FEATURES

ANALOGUE TO DIGITAL CONVERTERS AND THEN THERE WERE TRANSISTORS	February 12 Part 1 September 14 Part 2 October 24
ARTIFICIAL INTELLIGENCE — general	March 12
ARTIFICIAL INTELLIGENCE — neural networks	November 14
BBC RADIO DATA SYSTEM	January 12
BRainWAVE (ARTIFICIAL INTELLIGENCE)	March 12
CELL GUIDE	January 27
CONSTRUCTION SET COMPUTING (PCs)	March 14
CRYSTAL CLEAR (Crystals)	July 19
DRAM, INTERFACING	November 28
ELECTROMAGNETIC INTERFERENCE	March 11
ETCHING TANK AND LIGHT BOX CONSTRUCTION	April 14
GOOD IC GUIDE	October 30
	L165V power op-amp October 30
	TEA5570 radio IC November 30
	Power regulators December 40
INTERFACING DYNAMIC RAM	November 28
IN THE BEGINNING WAS THE VALVE	August 14
LANGUAGE LESSON	Part 1 January 24 Part 2 February 20
LESS LOGIC	October 36
LIGHT BOX AND ETCHING TANK CONSTRUCTION	April 14
LOGIC, DESIGN SIMPLIFICATION	October 36
MAKING TRACK (PCB Design on the PC)	September 21
MICROPROCESSOR LANGUAGES	Part 1 January 24 Part 2 February 20
NEURAL NETWORKS	November 14
NICAM 728 STEREO TV	February 16
NOISE ANNOYS (Circuit Theory)	Part 1 June 24 Part 2 July 19 Part 3 August 22
OP-AMPS (Circuit Theory)	Part 8 January 20 Part 9 February 24 Part 10 March 28 Part 11 April 20 Part 12 May 22
PC COMPUTER BUILDING FROM COMPONENTS	March 14
PC COMPUTER INTERFACING	June 13
PC COMPUTER PCB DESIGN REVIEW	September 21
RADIO DATA SYSTEM	January 12
READING BY NUMBERS	February 12
REFLEX ACTION (loudspeaker design)	July 29
RELATIVITY	July 13
ROCK CIRCUS	November 18
SAFETY FIRST	December 24
SKETCH 'N' ETCH	May 14
SOLAR POWER	March 23
SUN POWER	March 23
TESTING TESTING	Part 1 October 40 Part 2 November 21 Part 3 December 30
TRANSISTORS, AND THEN THERE WERE	Part 1 September 14 Part 2 October 24
UNDER SURVEILLANCE The Circuits	October 14
UNDER SURVEILLANCE The Inside Story	October 18
UNDER SURVEILLANCE The Telephone System	November 25
VALVES, IN THE BEGINNING WAS THE	August 14
VOICES FROM THE OTHER SIDE (NICAM)	February 16

## DON'T MISS Top Projects 1989

Next month inside ETI will be a free special issue — 68 pages containing the finest of our projects from the last twelve months.

## FREE INSIDE THE FEBRUARY ETI

## CIRCUITS

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# PCB

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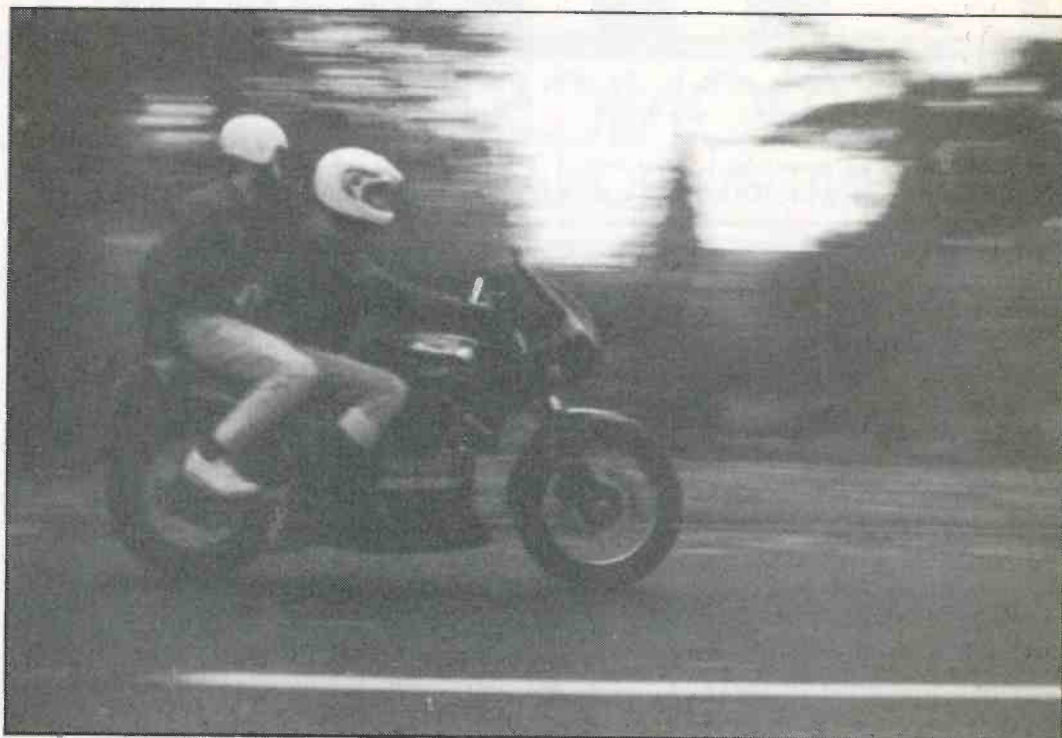
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# MOTORCYCLE INTERCOM



*Tim Oxtoby presents a voice-activated 2-way intercom with music input that puts an end to the annoyance of high-speed shouting matches*

PROJECT

**A**ny readers who have ever ridden a motorcycle will know how bored both the rider and passenger can get on long journeys. It was one such journey that inspired me to design this project.

After some thought I came up with the following design specifications. The intercom had to be relatively cheap and should be small and rugged enough to withstand life in a motor-cycle jacket pocket. It must have an input for an external source such as a personal stereo, and must be also be able to differentiate which of the incoming signals is passed to the main headphone amp. Lastly it must be economical to run.

So bearing all of this in mind the following idea emerged.

## Circuit Operation

Working from the block diagram in Fig. 1, the circuit operates in the following manner.

Essentially the input stages (the first two blocks) are the same circuit (see Fig. 2) using a 741 op-amp. The incoming signal from the mic is amplified by 100. This value is set by the resistors R2 and R3 (R9 and R10 for the rider). The circuit is of the basic non-inverting mode, the only difference being the addition of the resistor R6, the purpose of which is to add stability to the circuit as the 741 is running off a single rail supply.

This basic circuit I have found to be most useful. The 741 is led into believing that the supply is a dual supply by referencing the input and feedback loop to half the supply, in this case to  $\pm 4.5V$ . Capacitor C3 is used as a DC blocking cap.

The output of the op-amp is then split. One part is fed into the sensing circuit and then onto the control. The other is sent off to a simple transistor switch

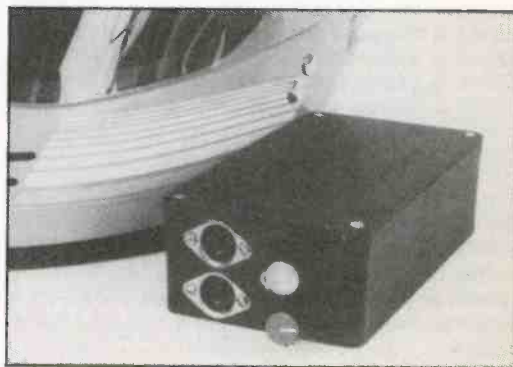
formed by R4 and Q1. It is the operation of this transistor to attenuate the signal at the appropriate time as the op-amp continuously monitors the incoming signal. This excludes the need for a second amplifier.

The sensing circuit comprises the diodes D1-3, R1 and C1. The three diodes in series are there to remove an offset of about 1.5V (three diode drops) arising because the 741 cannot swing down to ground. The diodes also rectify the audio signal which is then smoothed by the capacitor and fed into the input of the CMOS 4011.

The input impedance of IC5 is exceedingly high and as a result of this the capacitor would take too long to discharge. The addition of R1 allows the charge to leak away and the values of R1 and C1 determine the time the gate stays open.

## Turn The Music Up

Blocks three and four are the inputs for an external source, probably a personal stereo, and I have assumed that the signal will need no amplification or attenuation.



This part of the circuit works in the following manner. The incoming signal passes through a DC decoupling capacitor (C7,9) to remove any DC offset. Then a half supply offset is added to the signal so that the signal can swing equally between positive and negative, giving maximum volume without distortion.

The signal and offset are then controlled by the switch set up by R15 and Q3 for the left, and R19 and Q4 for the right.

It should be noted at this point that connected to the base of every transistor is a resistor to limit the current passing through the base-emitter junction, and a capacitor to decouple any oscillations that occur during the time that IC5 changes state.

The design could have incorporated several Schmitt triggers on the input to IC5 to introduce some hysteresis but this increased the complexity of the circuit and was found to provide no notable improvement.

## Control Circuits

As can be seen from circuit diagram, the control part of the circuit (block 10) is based around the CMOS 4011. Its purpose is to set the order of priority of the incoming signals, this priority being *rider*, *passenger* and *external signal* in that order.

A truth table for the logic states is shown in Table 1 and a description for readers not familiar with truth tables follows. To understand this you need to realise that where an output is 1, the transistor connected to that output will be turned on and fully saturated — no sound from that input will pass to the output. When the output is zero the transistor will be turned off — the sound passes. As mentioned earlier the transistor acts as a switch.

It can be seen that from the rider output that the output is the inverse of the rider input. As a result of this all other signals are turned off when the rider speaks, thus giving him or her full control (remember, 1 = sound off and 0 = sound on).

It should also be noted that to conserve the number of chips used, the results are obtained by effectively sharing gates. All the 'decisions' made by the unit happen almost instantaneously so that the unit can change between signals very rapidly.

The overall effect of the control circuit is to set a priority order for the inputs. This small amount of circuitry does this most effectively.

## Master Mix

Block eleven to thirteen (Fig. 1) are used by the unit to split the mono input of the mics ready for the stereo headphone amplifier. The problem is not splitting the signal but the mixing of all three signals together after the splitter. It would be highly undesirable to get crossover between the right and left channel.

Referring again to the circuit diagram, we have seen that at any time during the operation of this circuit there will be only one transistor on at any one time (with the exception of Q3 and Q4 as these are controlled by the same signal).

To explain this part of the circuit I shall pick the situation where the rider's gate is open and the other two (three if the external input is counted as two) are closed.

The signal is taken from the collector of Q1 and then enters the anodes of D7 and D8. The impedance of both of these branches is approximately the same and so the signals are approximately the same, you should also remember that all signals entering the mixer are on a  $\frac{1}{2}V_{cc}$  offset and that any transistor saturated appears to be ground to any signal in the mixer.



The output signal then passes through a potential divider set by two 10k resistors thus halving the signal which then carries on to the headphone amplifier.

To stop the signals crossing over from right to left they pass through diodes. Because of the offset on the desired signal and all other inputs being held at almost ground, the diodes will not conduct.

## Level Lifter

Blocks nine and fourteen form the headphone amplifier. The circuit is of similar form to the circuits in blocks one and two.

R32 and R33 set up the half supply, RV1 and R30 set the gain, C12 and R31 remove any offset and limit the output from the current from the 741. R29 is used to stabilise the circuit and C11 is used to block DC entering the amplifier.

## Power Supplies

The power supply for the unit comes from either one or two PP3 size batteries. Diodes D13 and D14 protect the circuit from being connected the wrong way around. They also select the stronger battery to power

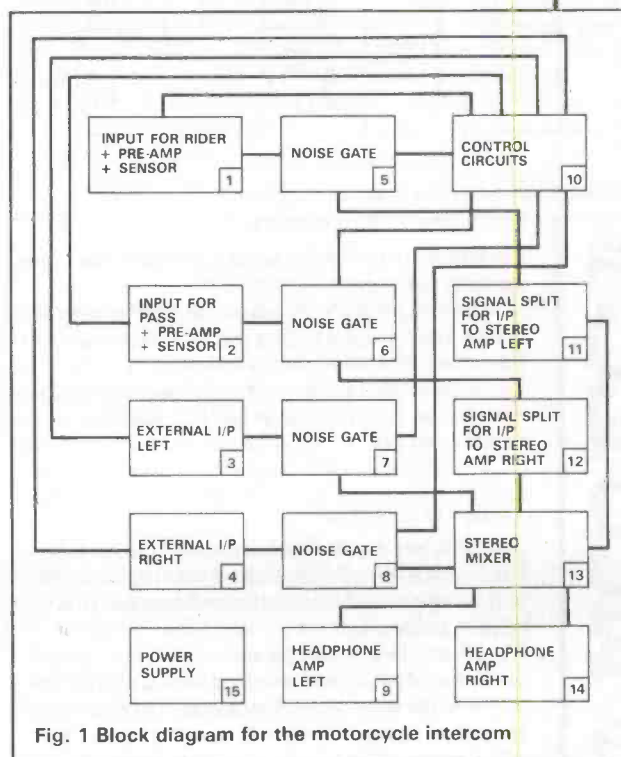


Fig. 1 Block diagram for the motorcycle intercom

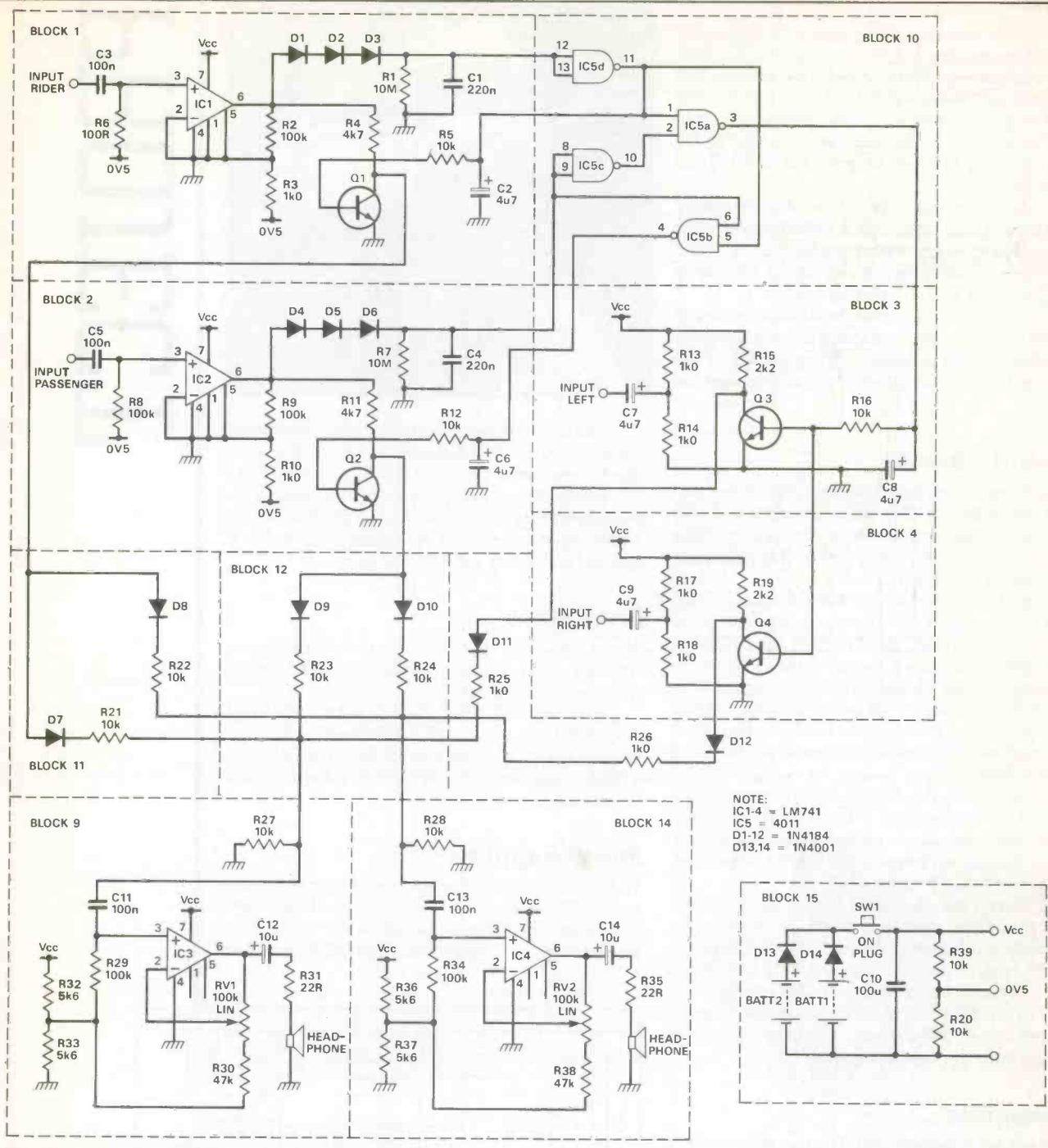


Fig. 2 Complete circuit diagram for the motorcycle intercom

# PROJECT

the unit so a new battery and a half-used battery may be used together.

SW1 is the main on/off switch, but this is located on the input/output socket and as a result the unit is turned off when the plug is removed.

C10 is used to decouple any unwanted signals that get into the supply lines and R39 and R20 set up a 1/2Vcc supply.

### Construction

The PCB (see Fig. 3) should be constructed as follows. For convenience all of the ICs are best held in sockets, and these can be fitted first followed by the links. Be as neat as possible!

Then solder in all of the resistors followed by the capacitors. Finally add the diodes and transistors.

Check your work for shorts, dry joints and polarity of components.

For the components mounted off the board try

to ensure good mechanical joints before soldering and make all wires long enough to do their job without being stretched but short enough not to make the job look messy.

Finally the decoupling capacitor must be connected between pins 14 (+ve) and 7 (ground) of IC5. It is very important to observe the polarity of this capacitor and hold your iron on the legs of this chip for the absolute minimum time possible.

Once again check that your work is clean — if it is then the unit is complete!

In my prototype I installed a normal pair of cheap headphones and microphone (Maplin type LB93B) into my helmet taking care not to damage the helmet.

*Very important! Do not under any circumstance drop your helmet or attempt to drill holes into it as this will weaken it considerably. Do not use any type or solvent based glues on your helmet as this will melt your helmet over time.*

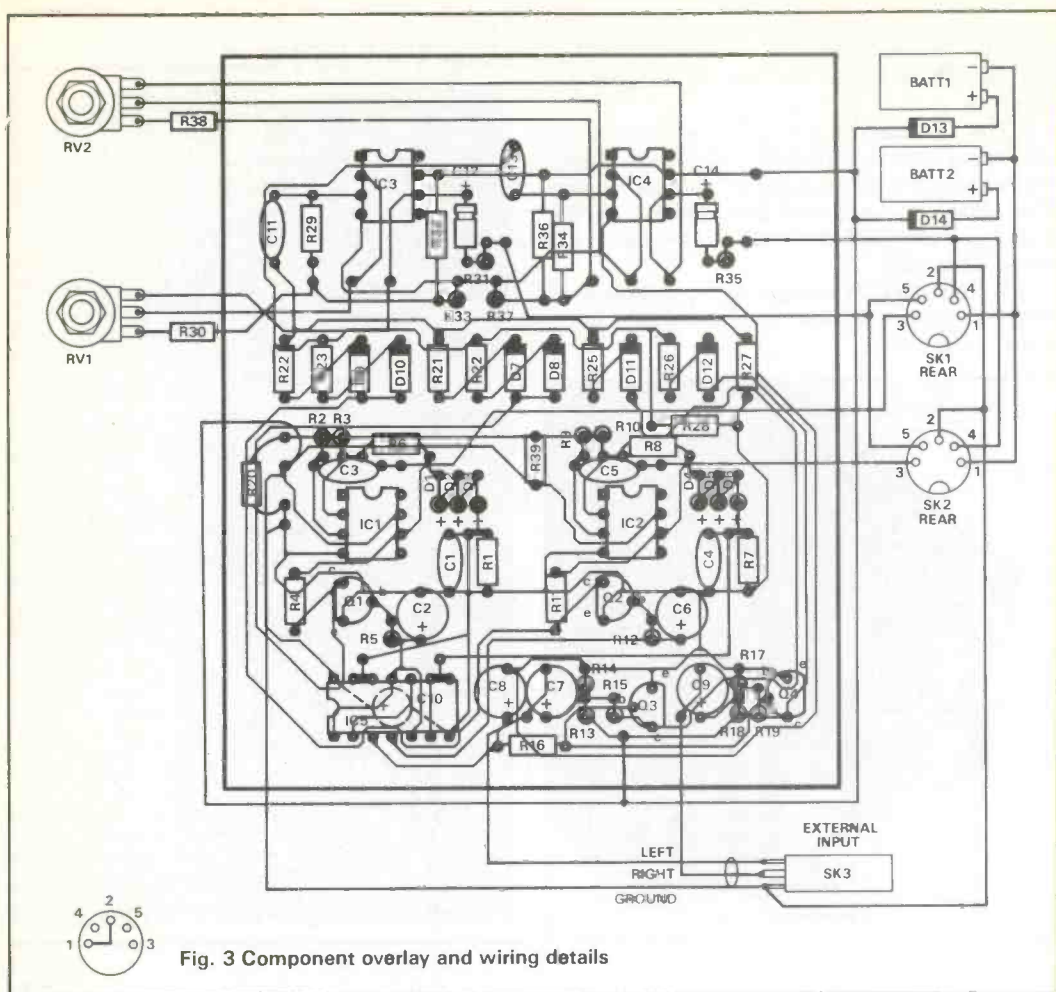
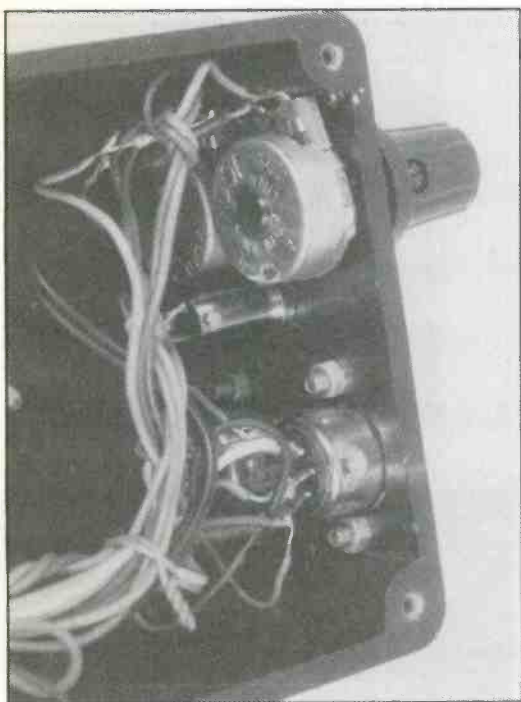


Fig. 3 Component overlay and wiring details



## Testing And Trouble Shooting

Ensure that all the components have been inserted with the correct polarity and that all chips have power and inputs. Inspect your work for dry joints and any bridging that may have occurred during the construction. Check all external wiring!

After the unit has been constructed and the headphones and mic inserted into the helmet, the unit can be tested. If it proves not to function as expected then the following trouble shooting may be followed.

As the unit was designed in blocks it can be tested in blocks. To check thoroughly you will need an oscilloscope and a signal generator, although a high impedance input voltmeter will do the job reasonably well.

To establish that the pre-amps IC1,2 are working correctly, compare their outputs (pin 6) to their inputs (pin 3) using a scope. If this is not possible check that pin 11 on IC5 goes low when there is an input to IC1 and pin 10 on IC5 goes low when there is an input on IC2. If Q1,2 are found to work correctly then it can be assumed that the amp, gate and detection circuit work correctly.

To establish that the control section works properly follow the truth table shown in Table 1.

Checking the external input can be done with a

Rider input IC5 pins 13,14	Passenger input IC5 pins 8,9	Rider out IC5 pin 11	Passenger out IC5 pin 4	External out IC5 pin 3
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	1	1

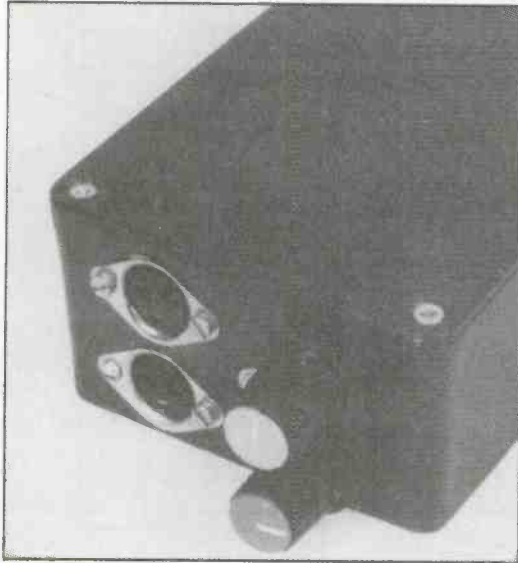
Table 1 IC5 control truth table for automatic input selection

# PROJECT

voltmeter. Ensure that there is  $\frac{1}{2}V_{cc}$  between R13,14 and R17,18 and that the transistors Q3,4 are switching.

The next stage is to check that the mixer is functioning correctly. Check all diodes are the correct way round and that there is about 0.6V drop on each of the diodes in the forward bias condition. By this stage the signal at R27,28 should vary between 0 and about half supply.

The signal is then passed to the headphone amp which is used to match the impedances of the mixer to the headphones.



## PARTS LIST

### RESISTORS (all $\frac{1}{4}W$ 5%)

R1,7	10M
R2,6,8,9,29,34	100k
R3,10,13,14,17,18,25,26	1k0
R4,11	4k7
R5,12,16,20-24,27,28,29	10k
R15,19	2k2
R30,38	47k
R31,35	22R
R32,33,36,37	5k6
RV1,2	100k lin

### CAPACITORS

C1,4	220n
C2,6-9	4.7 $\mu$ electrolytic
C3,5,11,13	100n
C10	100 $\mu$ electrolytic
C12,14	10 $\mu$ electrolytic

### SEMICONDUCTORS

IC1-4	LM741
IC5	4011
Q1-4	BC174
D1-12	1N4184
D13,14	1N4001

### MISCELLANEOUS

BATT1,2	PP3 battery
SK1,2	5-pin DIN
SK3	3.5mm stereojack

PCB. Battery clips. Knobs. Case. Wire. Nuts and bolts. IC sockets.

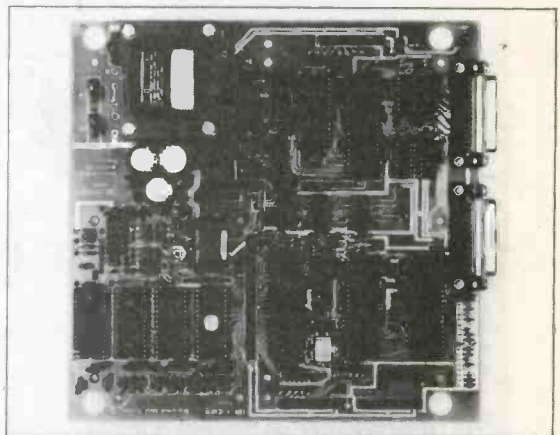


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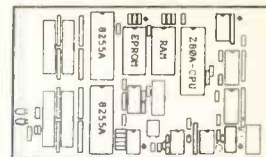
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A star feature is that no special or custom chips (ie PALs, ULAs, ASICs etc) are used — and thus there are no secrets. The Z80A is the fastest and best established of all the 8-bit microprocessors — possibly the cheapest tool

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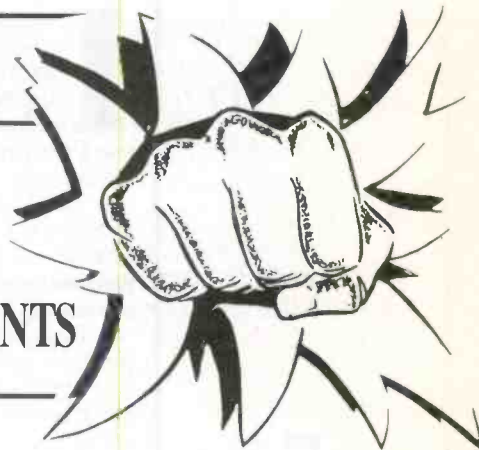
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**I**n the world of hobbyist test gear, the function generator comes pretty high on the list of essential items for the lab bench. Surprise surprise however, commercial units can cost an arm and a leg. The expense of such equipment makes it a prime candidate for home construction.

Almost all such designs are based on the industry standard ICL8038 chip and have a fair degree of similarity as a result. The design presented here operates on a slightly different principle, for a number of reasons.

Firstly it is more interesting to approach the problem with some fresh thought rather than repeating earlier concepts, handy though they may be. Of course one should try to avoid reinventing the wheel.

Secondly for this generator it was desired to provide voltage control for both frequency and amplitude. Thirdly the technique used for sinewave generation has certain advantages. Function generators usually generate a sine wave by soft clipping a triangular wave using an arrangement of diodes or similar. While the resulting distortion can be kept fairly low, that which remains tends to be composed of high-order harmonics due to the abrupt actions of the clipping circuit.

This design passes the triangle wave through a low pass filter. Although the filter used is a fairly simple one and does not eliminate distortion completely, that which remains is of a lower order and produces a less spiky output better suited for the testing of audio amplifiers and so on.

Obviously in order to achieve a constant output level, the filter cut-off frequency must be made to track the signal frequency. This has been achieved by making both the oscillator and filter voltage controlled.

### Construction

The construction is fairly straightforward, with most of the components being mounted on the single sided PCB (see Fig. 2).

Begin construction with the wire links and PCB pins for off-board connections, then add the IC sockets if you're using them.

Note that two of the links (near the transformer) cross over each other — obviously one or both of them will need to be insulated.

The rest of the components can then be inserted in order of height. Do not add ICs 1-4 yet, and pay special attention to the polarity of C14,15 and the rectifier, since the reversal of any of these may cause loud noises and acrid smoke! Transformer T1 has its secondary tags connected to the PCB with short lengths of wire, the two central ones having first been linked. Note also that IC5 and IC6 will not require heatsinks.

The off-board wiring is best done with rainbow ribbon cable as this aids both neatness and ease of identification. This is all shown in Fig. 2. Obviously the mains wiring can not be ribbon cable and must use mains rated cable.

The switch SW3 is shown as a toggle type (see *Buylines*) but any sort of 3-way switch can be substituted. The output socket SK2 could also be chosen as you wish but bear in mind that the BNC or phono type will connect the circuit ground to the case (and therefore to mains earth) and if this is not desired then an insulated socket should be used.

In the prototype the circuit board was housed in a small aluminium box of the dimensions specified in *Buylines*. This makes the front panel work fairly crowded — but then it's economical on space and it makes the box cheaper. For screening purposes a metal case is definitely recommended. The prototype was given a couple of coats of matt black spray paint and labelled with rub-down transfers. Good and smart (see photographs).

### Setting Up

A multimeter with a fairly low DC range is required

PROJECT

Dom Banham presents  
a budget function  
generator for the  
workshop

# PROJECT

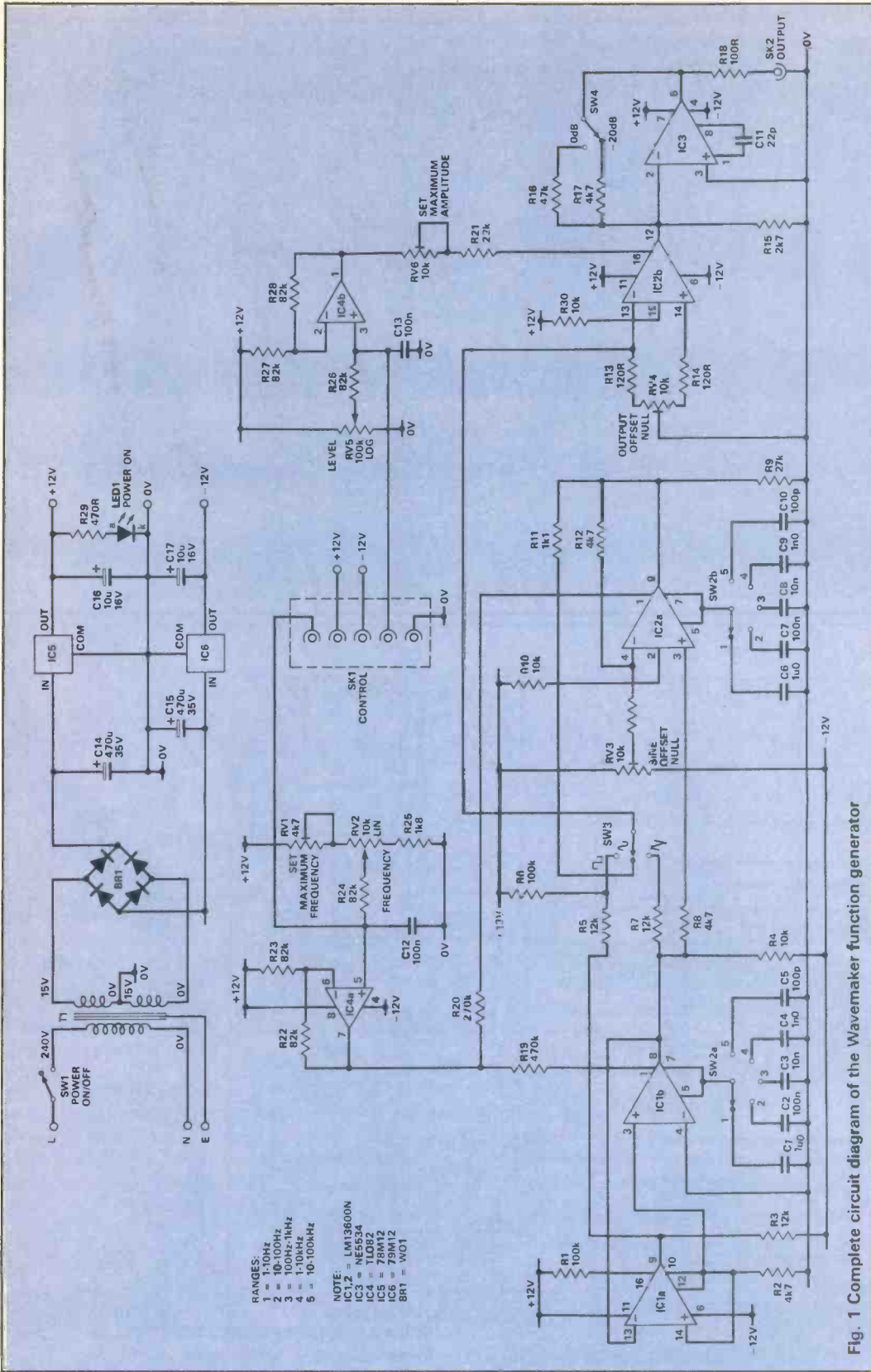


Fig. 1 Complete circuit diagram of the Wavemaker function generator

to set up the unit. A scope, if you have one, is also useful to check the waveforms.

Connect the unit to the mains and switch on. The LED should light and  $\pm 12V$  should appear on the relevant IC pins. If not, switch off immediately and check the power supply circuitry — using great care to do so of course.

Now insert ICs 1-4 and set all presets to mid position. Select range three on SW2, set SW3 to 'triangle' and SW4 to 0-5V. Take RV2 fully clockwise and RV5 fully anticlockwise. Now check all these again in case you got confused.



## PARTS LIST

### RESISTORS (all 1/4W 5%)

R1,6	100k
R2,8,12,17	4k7
R3,5,7	12k
R4,10,30,31	10k
R9	27k
R11	1k1
R13,14	120R
R15	2k7
R16	47k
R18	100R
R19	470k
R20	270k
R21	22k
R22-24,26-28	82k
R25	1k8
R29	470R
RV1	4k7 cermet preset
RV2	10k linear
RV3,4,6	10k cermet preset
RV5	100k log

### CAPACITORS

C1,6	1u0 polyester layer
C2,7	100n polyester layer
C3,8	10n polyester layer

C4,9	1n0 polystyrene
5,10	100p polystyrene
C11	22p polystyrene
C12,13	100n dipped polyester CZ80
C14,15	470u 35V radial electrolytic
C16,17	10u 16V radial electrolytic

### SEMICONDUCTORS

IC1,2	LM13600N
IC3	NE5534
IC4	TL082
IC5	78M12
IC6	79M12
LED1	panel mounting LED
BR1	W01 bridge rectifier

### MISCELLANEOUS

SK1	6-way PCB-mounting DIN socket
SK2	see text
SW1	mains on/off switch
SW2	2-pole 6-way rotary switch
SW3	1-pole 3-way toggle or rotary
SW4	spdt toggle
T1	15V+15V 10VA transformer
Case, PCB, Nuts, bolts, wire etc.	

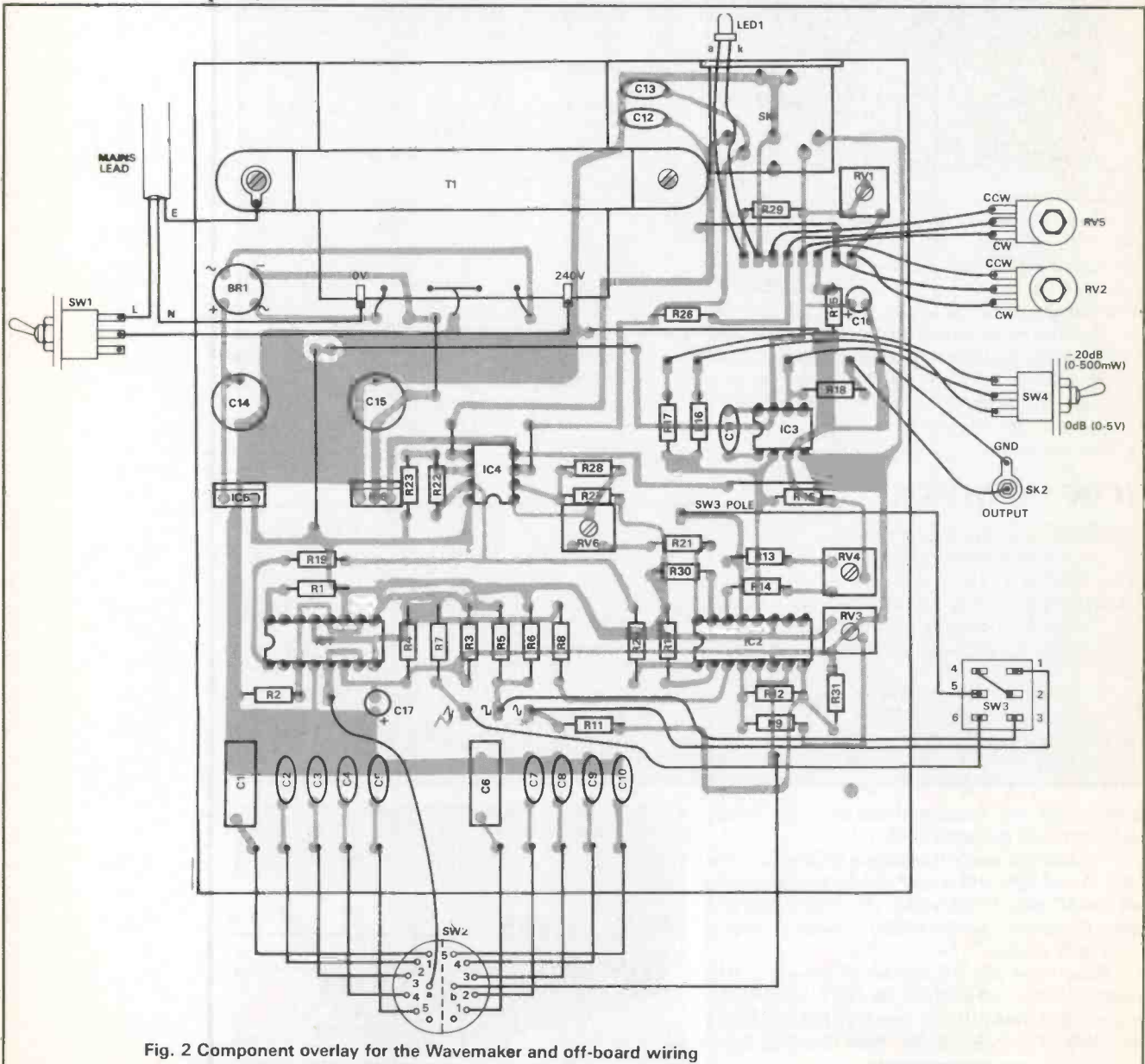
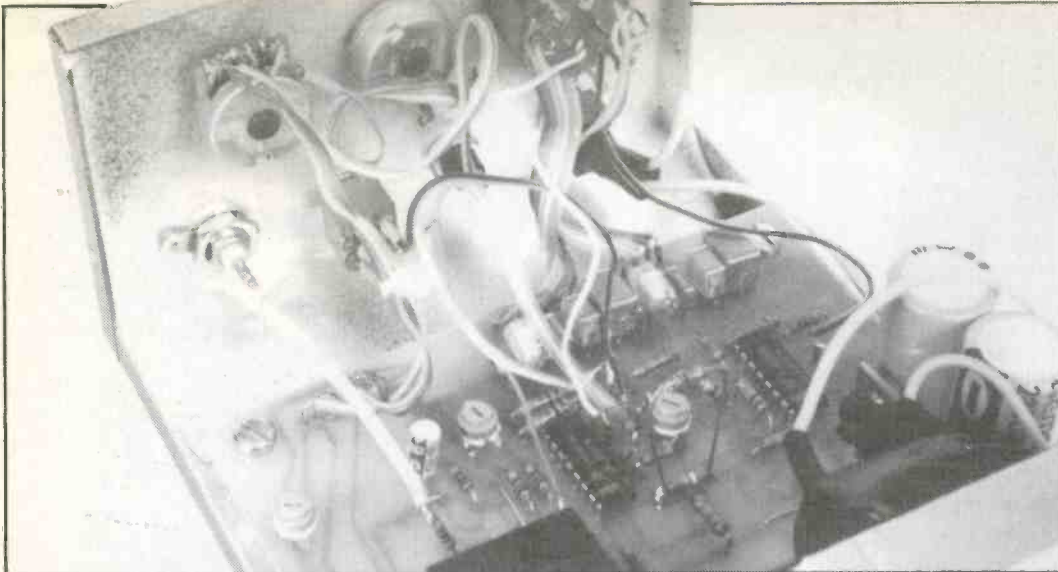


Fig. 2 Component overlay for the Wavemaker and off-board wiring



Now connect a scope or voltmeter to the output. Switch the unit on and rotate RV5 clockwise slowly. A large DC offset will probably appear. Adjust RV4 to cancel this then switch SW3 to 'sine' and adjust RV3 to cancel any offset that appears again.

If you do have a scope you can now use RV1 and RV6 to set the maximum frequency and amplitude to 1kHz and 5V peak respectively. If you haven't then set RV6 to the mid position and replace RV1 with a 1k5 resistor. This will give good enough calibration for most purposes.

## HOW IT WORKS

The complete circuit diagram is shown in Fig. 1.

The mains oscillator circuit is formed by IC1, a LM13600 dual OTA (operational transconductance amplifier). This is connected in a circuit similar to that of the standard square/triangle wave generator.

IC1b acts as an integrator or ramp generator with the slope determined by the current flowing into pin 1 (thus allowing voltage control).

IC1a operates as a Schmitt trigger with its trigger levels centred about the 0V line. The timing capacitor is selectable for different frequency ranges by SW2a. The square and triangle waves are available at a level of 1V peak from pins 9 and 8 respectively, and are fed to waveform selector switch SW3 by level matching resistors R5 and R7.

Due to the buffer stage in IC1a, the squarewave output has an offset of about -1V. R6 adds a small current to correct for this.

The triangle output is also fed via R8 to IC2b which is configured as a voltage controlled filter arranged to track the oscillator frequency, which filters the triangle wave to give a fairly good sine wave. Although the filtering is fairly gentle the output is quite clean and rather more sinewave-like than that produced by the more usual method of passing a triangle wave through non-linear circuits.

The filter is voltage controlled in parallel with the oscillator so the relationship input frequency to filter cut-off frequency is constant.

With a scope connected to the output, clean square, sine and triangle waveforms should be visible and the amplitude should be variable with RV5 and SW4. Frequency should be variable over a 10:1 range with RV2 and in decade ranges with SW2. If the sine output on any range is either weak or distorted, check that C6-10 are wired to the right terminals of SW2b (you might have got it wrong, even with ribbon cable!).

And so, the function generator is now ready for use.

Finally here are a few points about the design for readers who enjoy playing with designs.

- C12 and C13 were included in the prototype to prevent stray pick-up at the control inputs. If these inputs are connected to external equipment then you can take out the capacitors.
- The LM13600 ICs can be replaced by LM13700s if available, but performance may drop a little at low frequencies.
- For applications needing more output power at low frequencies, a higher power op-amp such as an L165 may be fitted in place of IC3. IC5 and IC6 will then need heatsinks and the values of C14 and C15 will need to be increased to about 2200µF.

This ensures that the sinewave amplitude is similar at all frequencies. The resulting sinewave is fed via R11 to SW3. RV3 is an offset-null control.

From SW3 the chosen output is taken to IC2b, a fairly conventional VCA. This gives an output in the form of a current which is converted to a voltage output by output stage IC3, which has switchable gain (via SW4) to allow fine control at low output levels.

The control voltages for the VCO/filter and the VCA swing both positive and negative with respect to 0V. Since it is convenient that any external control signals be purely positive going, IC4a and b provide gain and level matching.

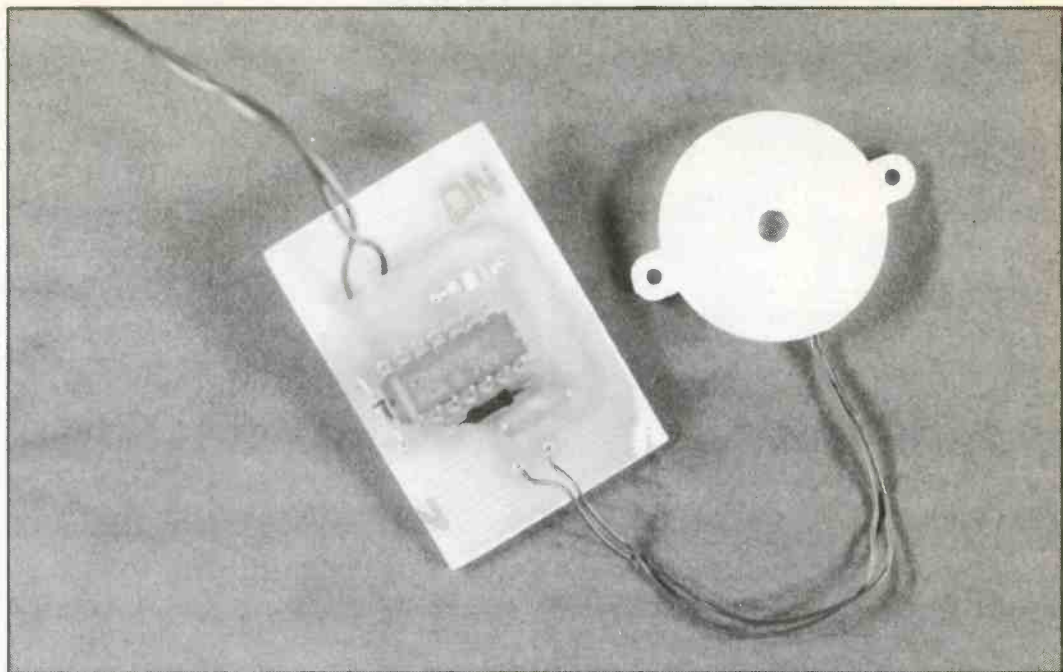
RV2 and RV5 provide local control of frequency and amplitude. Using a log pot for RV5 will give rather smoother control at low levels.

The power supply based around T1, BR1, C14-17 and IC5/6 is pretty much standard and should need no particular explanation.

## BUYLINES

Most components can be obtained from any supplier. IC1,2 can be obtained from Watford Electronics, tel: (0923) 37774.

The case in the prototype measured 130 x 180 x 75mm. The PCB can be obtained from ETI's PCB Service (see centre pages).



## LOW VOLTAGE ALARM

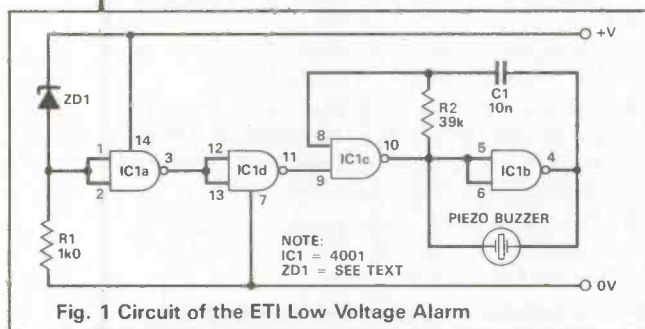


Fig. 1 Circuit of the ETI Low Voltage Alarm

Keith Brindley warns of early battery failure with this simple project

Simple though it is, the ETI Low Voltage Alarm serves a most useful purpose. It warns you (before it happens) of impending battery failure, so that you can dash off to the shops to buy new cells before your equipment stops working altogether.

Its small size and low current consumption means that you can build it into the equipment for which the voltage is to be monitored. Then, when the battery voltage begins to reduce at the end of the battery's life, the shrill piezo buzzer of the project will sound to warn you that the battery has effectively finished.

The circuit, shown in Fig. 1, couldn't really be simpler. Only one CMOS integrated circuit is used, together with just a handful of commonly available components.

### Construction

As in all *1st Class* projects there are two methods of construction: PCB and stripboard. Choice of which to use is left entirely up to the reader. Without any doubt, a PCB constructional method gives the neatest, best looking and most straightforward project, but the stripboard method alleviates the necessity to make a PCB or buy one from the PCB Service in this issue of ETI.

Whichever you choose, procedure is similar. PCB overlay, component layout and wiring details are shown in Fig. 2. Stripboard overlay, component layout and wiring details are shown, similarly, in Fig. 3.

Solder all passive components first: resistors, capacitor, and for the stripboard — wire links. It's a good idea (though by no means essential) to insert PCB pins at hole positions of all off-board connection points. This makes soldering of the connections easier when the board is fully populated with components.

Next, solder in the zener diode. Your choice of value should be taken after reading the *How It Works* section, which explains how the project works and how to select a zener diode value.

You can either solder the integrated circuit IC1 directly into the board, or use an IC socket of some description. A socket is useful if at some later time you intend using the IC in another circuit. If you have no intention of this, perhaps you might like to solder the IC in. Soldering of integrated circuit pins should be undertaken carefully, avoiding too much heat which can damage the IC internally. As a precaution allow the IC to cool after soldering one pin before you solder in the next.

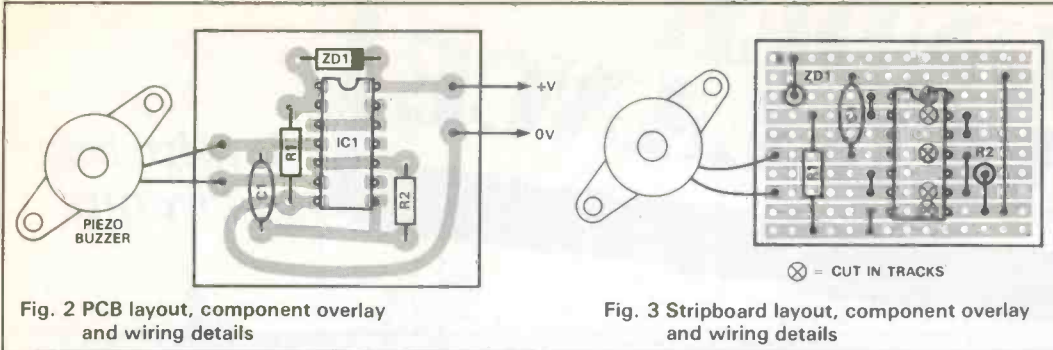
After all the components have been soldered in, make all off-board connections, that is, to the piezo buzzer and the project's power connection leads. This is where the use of PCB pins, mentioned earlier, makes things a bit easier. They really are worth investing in.

### Testing

To make sure your project is working properly, you should have a power supply with a continuously variable output voltage and a voltmeter, capable of reading the voltage range covered by the power supply.

Connect the voltmeter to the power supply, to measure the output voltage. Set the power supply output to a voltage higher than you want the project to sound its alarm. So, if you wanted your project to sound when voltage falls below, say 7V, set the power supply to about 10V.

Now, connect your project to the power supply. If your choice of zener diode is correct, nothing should happen.



## HOW IT WORKS

Figure 4 shows a block diagram of circuit operation. If you compare this with the circuit diagram of Fig. 1 you'll get a good idea of how the project works.

The voltages reference is formed by zener diode ZD1 and resistor R1. You should note that, unlike the normal uses of zener diodes in say power supplies, the diode and resistor are inverted. That is, the zener is connected to the positive power rail while the resistor is connected to the negative rail.

All this means is that the reference voltage maintained by the zener across itself is always more positive with respect to the voltage across the resistor. Because of this, the voltage applied to the input of gate IC1a is not fixed with respect to ground (as it would be in the more conventional method of zener diode use) but is instead fixed with respect to positive supply voltage. In effect, as the supply voltage rises or falls, the gate input voltage rises or falls in a fixed manner.

As the gate input voltage varies with changing power supply voltage, the switch-point at which the gate switches from a high to low state is crossed. Thus the gate switches as the power supply drops. This can be seen by considering the graph in Fig. 5, where three curves are shown. The first (curve A) shows how the gate switching voltage changes with varying power supply voltage.

Curve B on the other hand shows the voltage applied to the gate input due to the zener diode voltage reference with a zener diode voltage of 3V. Curve C shows a curve for a zener diode voltage of 6V.

Looking at these curves you can see how the gate switches when the power supply voltage is around 5V for the 3V zener diode and at around 12V for the 6V zener diode.

Even though these graphs are arrived at empirically, you should get the idea: by changing the zener diode voltage, you change the gate switching point as the power supply voltage falls. So, you can insert the zener diode of your choice, to suit the voltage range you wish to monitor.

Table 1 lists a number of commonly available zener voltages and the approximate switch point voltage of the power supply. So, if you wish the project to sound the alarm when power supply voltage falls to around 11.5V, use a 5V6 zener diode. If the alarm is to sound when voltage has fallen to around 7V, use a 4V7 zener diode. All voltages are dependent on individual components (both zener diodes and gate switching voltages are slightly variable) so you may need to experiment.

Gates IC1d & c form the low voltage trigger. The gated astable multivibrator is formed around gates IC1c & b, together with associated components. The piezo buzzer is driven in anti-phase by the astable multivibrator. Thus when the power supply voltage is above that which causes the zener diode voltage to be above the first gate's switch point the buzzer does not sound. However, as the power supply voltage falls, taking the first gate's input voltage below its switch point, the buzzer sounds.

Slowly lower the power supply output voltage, simultaneously watching the reading on the voltmeter. At some lower voltage, the piezo buzzer should sound, indicating the project works. At voltages below this point the buzzer sounds, voltages above the point will cause the buzzer to stop. If your choice of zener diode is correct, the voltage point at which the piezo buzzer sounds will be your selected voltage.



## PARTS LIST

- RESISTORS** (all 1/4W 5%)  
 R1 4k7  
 R2 39k
- CAPACITORS**  
 C1 10n
- SEMICONDUCTORS**  
 IC1 4001  
 ZD1 see Table 1 and text
- MISCELLANEOUS**  
 Piezo buzzer  
 IC socket  
 PCB or stripboard

## BUYLINES

No component will give any difficulty in procurement: they are all extremely common components. Either your local outlet, or any of the mail order companies who advertise in ETI will be able to provide you with all components. A PCB can be purchased from the ETI PCB Service (see centre pages).

Table 1 Zener and trigger voltages

Zener diode voltage	Approximate trigger voltage
3V0	5V
4V7	7V
5V7	11V5
6V8	13V8

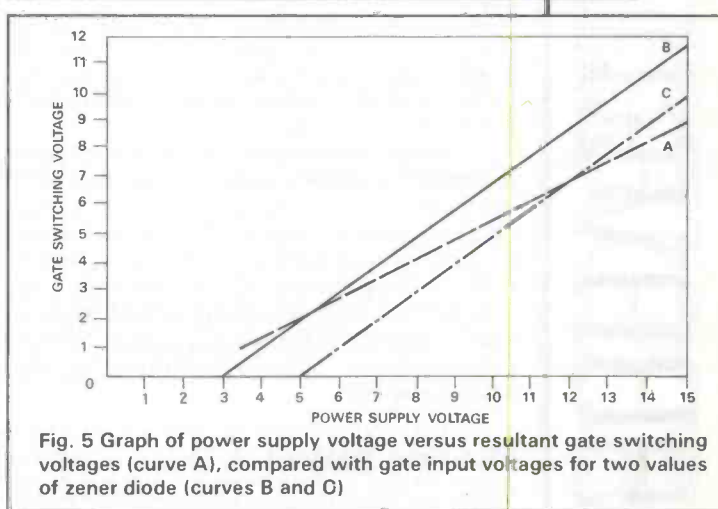
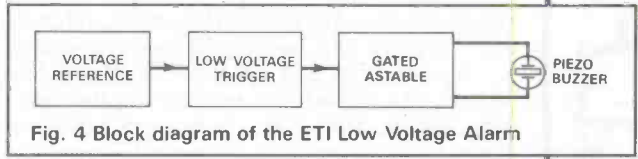


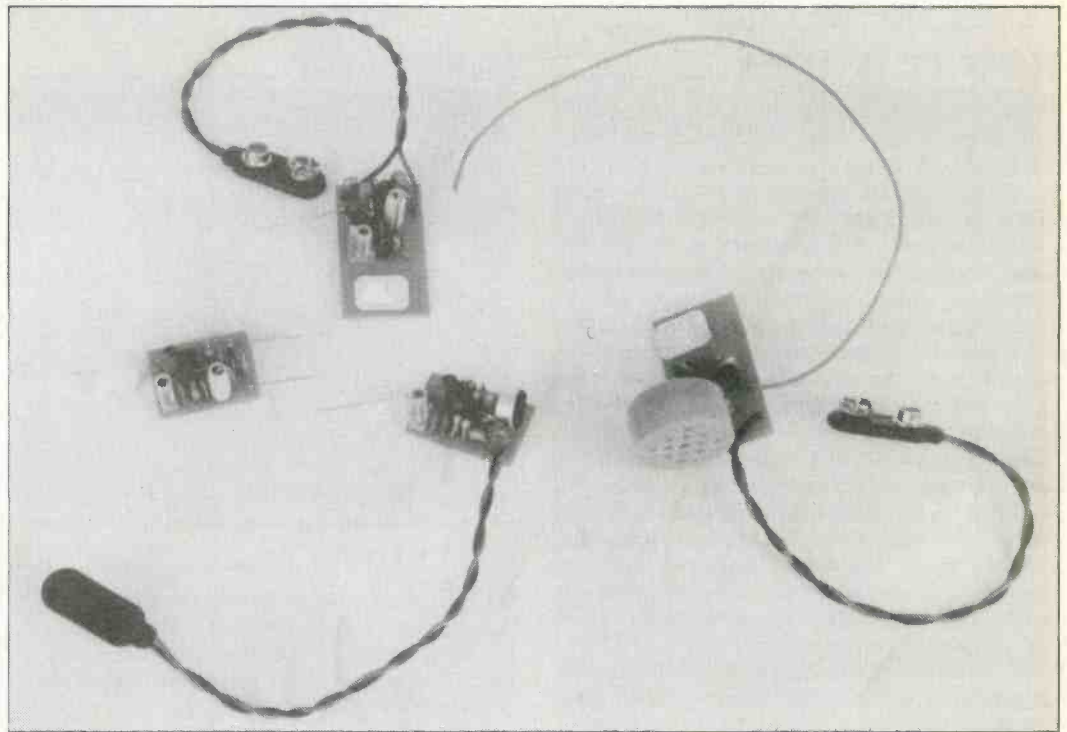
Fig. 5 Graph of power supply voltage versus resultant gate switching voltages (curve A), compared with gate input voltages for two values of zener diode (curves B and C)

# UNDER SURVEILLANCE

## 5: Mini bug circuits

Use your free PCB to build a variety of novel surveillance projects. Paul Chappell helps you with the construction

# SURVEILLANCE



**J**ust when you thought it was safe to talk on the telephone... The PCB from the cover is about the closest thing you'll find to a home spying kit. There is indeed a telephone bug, and believe me it's one that the professionals would be pleased to have in their kit bag for a routine surveillance operation. There's a voice transmitter, very sensitive indeed with excellent clarity and a most respectable transmitting range. There's the bug detector board for last month's project, and finally the PCB to use with last month's free components.

Your first task is to split the PCB into the four sections. The places to cut are shown by the dotted lines. The best tool for the job, assuming you're not equipped with a guillotine, is a small hacksaw. Cut carefully to avoid chopping any of the tracks or pads. Don't try it with shears or any tool that might bend the board — you may get away with it on fibreglass, but the bonded paper material of your free PCB is brittle and the board will split.

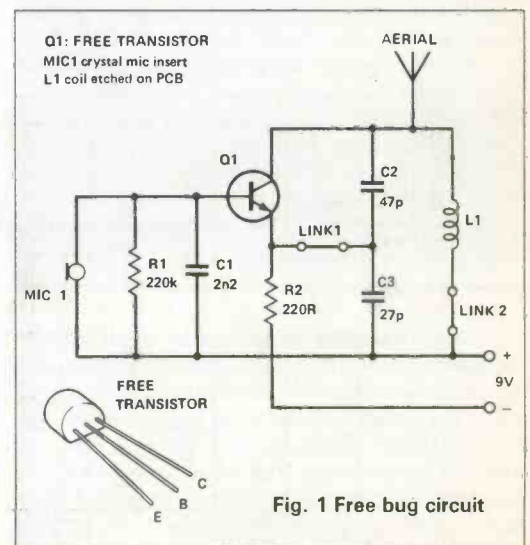
The smallest board is for last month's bug detector project, so if you've been waiting to build that one, off you go and do it. The two slightly larger ones are for the telephone and voice bugs. I'll tell you how to build these later. The largest board of all, the one with the spiral pattern at one end, is for the free project, and that's the one I'll begin with. If you missed last month's free components, by the way, all is not lost. There are some spare ones — see *Buylines* elsewhere in this article for details.

### The Free Project

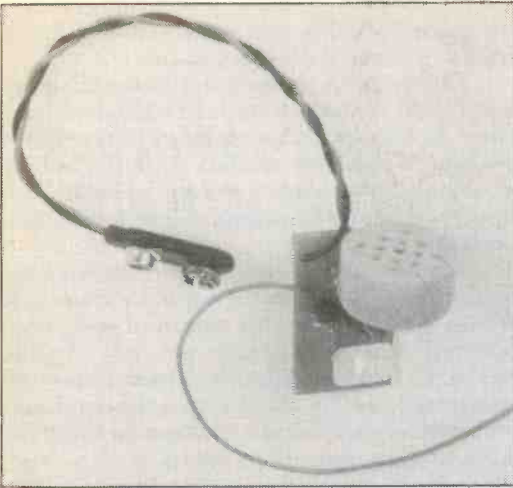
When the time came around for this year's free project,

I was very keen on the idea of giving away a bug. Right up until the last moment I thought it would be impossible — how can you possibly make a bug with half a dozen components? Eventually, by etching the coil onto the PCB and getting as much work as possible from the remaining parts, I just about managed it. The circuit is shown in Fig.1.

It has to be said that because of certain compromises from paring the circuit to the very core, the performance is not in the top league. In fact it would have difficulty qualifying for the middle league. But you will hear your voice on the radio, and what could be more thrilling than that?







The component layout for the project is shown in Fig. 2. So long as you use a suitable soldering iron (a 15W one with a slim bit), seat the components comfortably against the board (no long 'legs') and make absolutely sure not to short out adjacent tracks, everything should be fine. The microphone must be a crystal type — others won't have sufficient output and will in any case upset the operation of the circuit.

Now for the test. Put the bug close to an FM radio receiver and tune slowly across the dial. When you hit the right spot in the band there will be a loud whistle as the microphone picks up the sound from the radio and feeds it back again, setting up oscillations around the loop. Take the bug away from the radio, the whistling should die down, and you're in show biz: sing, tap dance, do a cabaret routine, and there it is reproduced on your radio (and probably your neighbour's too, for that matter).

The transmitter, you'll find, is somewhat sensitive to handling and will drift out of tune from hand capacitance. This can be an advantage when you're tuning the radio in the first place; if you're approaching the proper frequency from below you can gently squeeze the coil between finger and thumb, and you'll hear a 'whump' from the radio as your fingers tune the bug past the radio's frequency. The closer you come to the proper tuning, the less of the coil you'll have to cover to get the 'whump'. Who needs a frequency meter?

There are a number of ways the performance of the circuit can be improved, and if you're an experimenter at heart you can see the right direction to head in by comparing Fig. 1 with the infinitely better circuit of Fig. 5. Otherwise, you might like to have a go at my next circuit, shown in Fig. 3.

This one is the exception in that it isn't specifically intended to be a bug. There are all kinds of uses for a radio transmitter and what I had in mind for this one

was a leadless electric guitar. That is to say, instead of connecting the guitar to the amplifier with a length of wire, you make a radio link instead. You can buy transmitters for this purpose, but all the ones I've seen have a price tag totally out of proportion to the cost of the electronics inside. This one can be built for the price of a decent guitar lead, and although I wouldn't have absolute confidence in it if you're about to play at the Colston Hall, Hammersmith Odeon or wherever (crystal frequency control and a transmitting frequency outside the broadcast band would be the main modifications) it's fine for practice and for gigs on the pub and club circuit.

Frequency modulation is achieved with a tuning diode. All diodes have, to a greater or lesser extent, a junction capacitance which varies with voltage. Tuning diodes are specially made to magnify this characteristic, so that on the low cost ones you can get something of the order of a 2:1 capacitance change, and for the exotics 20:1 or more. These are sometimes called varactor diodes, or variable capacitance diodes. I'll call them tuning diodes, which neatly sums up their purpose. If you want to know where to get them from, please don't call us. Look at the *Buylines* section elsewhere in this article.

If you want to use your free components for this circuit instead of Fig. 1, use the free transistor as Q1, not Q2, since the components around Q2 have been specified to suit a ZTX300, whereas those around Q1 are for most transistors. Since the free transistor has a far higher transconductance than the Ferranti device (yes, transconductance is important in certain bipolar transistor circuits, like this one) you may find that the modulation is excessive, causing a certain amount of distortion. There's no easy way around this, other than to use the specified transistors for Q2 and Q1. You may get away with tuning down the guitar's volume control close to minimum, or you might find it better to omit C2, which will reduce the gain considerably.

The circuit layout is shown in Fig. 4. Once again,

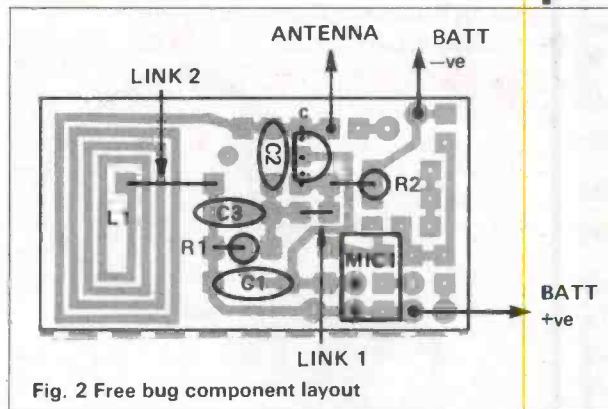


Fig. 2 Free bug component layout

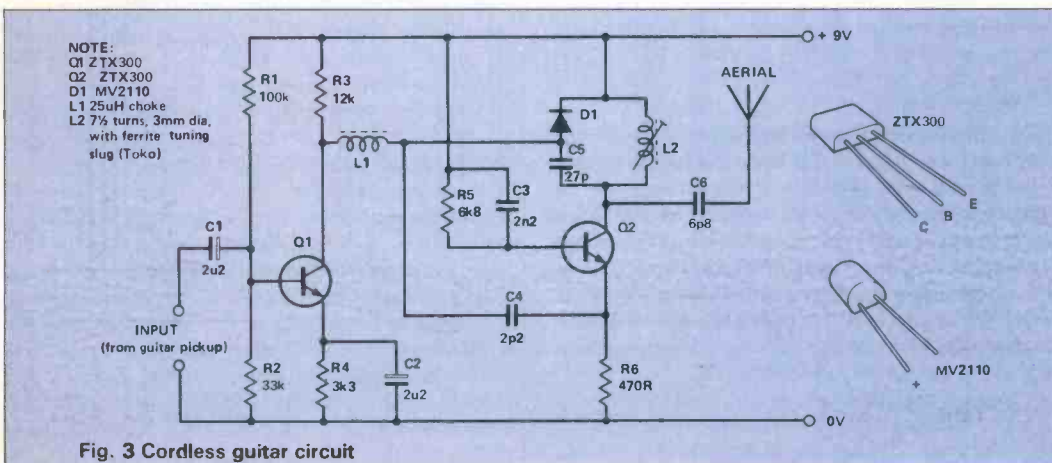


Fig. 3 Cordless guitar circuit

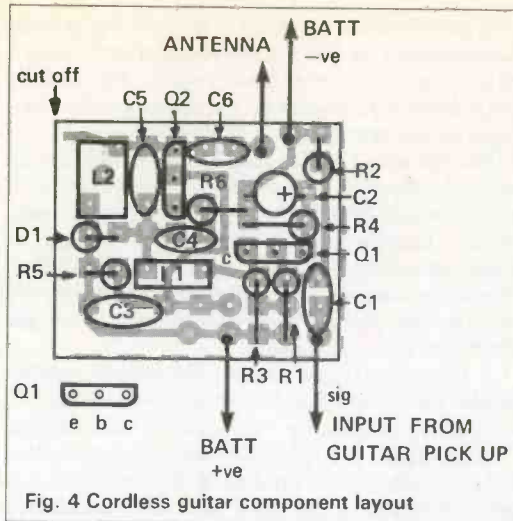


Fig. 4 Cordless guitar component layout

there's nothing to cause any difficulty except that it's all too easy to solder across adjacent pads. Check the circuit thoroughly when you've finished to make sure there aren't any shorts, and for heaven's sake don't try soldering it with that monster iron you use for repairing car electrics!

When you're tuning up the circuit, treat the tuning slug in the coil as if it were a Ming vase. It's very brittle and if you break it (as many of you will), that's the end of the coil. Metal screwdrivers, and even metal trim tools, are a no-no. It's plastic every time. If you haven't got a trim tool, a few minutes spent filing down a plastic knitting needle will be time well spent.

To tune up, either set the radio to mid-band and tune the coil, or set the coil slug 1mm from the top of the former and tune the radio. When you hit the right frequency you'll know it by the sudden decrease in the volume of hissing from the radio. Otherwise, you can temporarily connect a microphone to the input and listen out for the whistling, as for the bug circuit. Or have somebody twang the guitar and listen out for the sound. The choice is yours.



### Room Bug

I must admit that this one impressed even me. Where electronics is concerned, I've been there, seen it, done it, got the tee-shirt, as they say. There's not a lot that elicits more than a slightly raised eyebrow or a stifled yawn. But to hear this one go gave me the biggest buzz I've had in years (from electronics, that is!) The thing is, if a large and complicated circuit performs well, so what? You expect it. But to hear a little two-transistor job give better clarity than a BBC broadcast, now that's something else entirely. I love it.

As far as sensitivity goes . . . well, I won't spoil it for you. When you come to try it out, remember that it is a bug, so don't speak directly into the microphone.

Put it a couple of feet away, or on the other side of the room if you like, and speak normally. Speak quietly. Whisper. It will pick it all up.

The circuit for the project is shown in Fig. 5a. Once again I've used Ferranti ZTX300 transistors, which are ideal for FM bug making. The slim 'E-line' package is about the smallest you'll get without resorting to surface mount, and an  $f_t$  of 150MHz for the ZTX300 means it has plenty of oomph at the frequencies of interest.

The microphone is an electret insert. The one I used in the prototype was the two wire version — it's smaller than the three wire type. If I'd really been pushing for the tiniest possible size, they do come smaller still. Connections for the alternative three-wire type are shown in Fig. 5b. R1 will not be needed, and the power connections are available on the PCB if this is the only type you can get hold of.

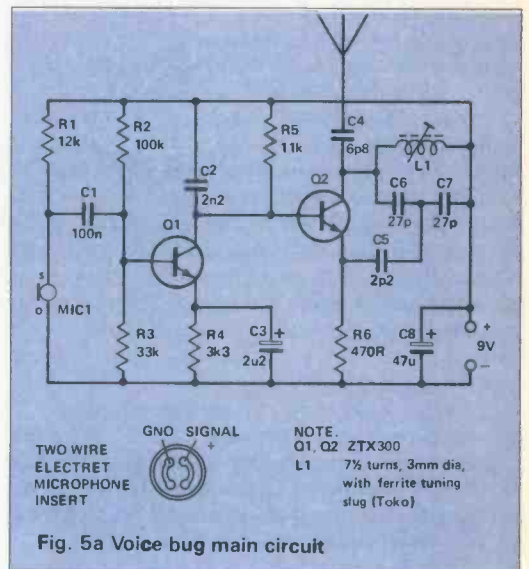
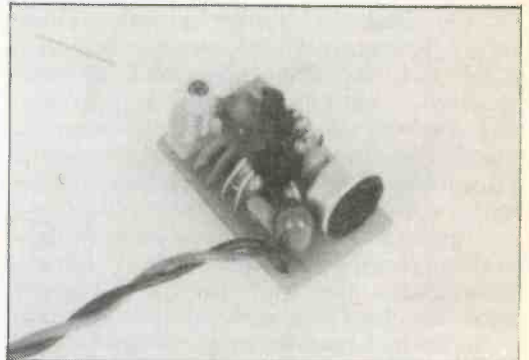


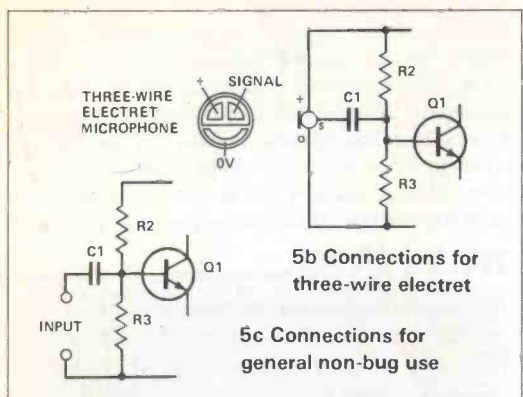
Fig. 5a Voice bug main circuit

Figure 5c shows the way to adapt the circuit for general use, another guitar transmitter, or maybe even your own FM local broadcast station! Miss out R1 and take the input directly to C1. You'll very likely find that the circuit has more audio gain than you need. This can be set right by missing out C3.

Figure 6 shows the PCB layout for the project. this board is even more crowded than the earlier circuits, so do take great care not to let solder run between adjacent pads. You'll notice the cunning space-saving manoeuvre of soldering R3 to the back of the board... OK, I can't get away with that. It's a fair cop, guv. I thought I'd be able to save space by missing it out, but the circuit needs its. Solder it on last of all.

Tune-up time. Once again I must stress that the ferrite core in the coil is brittle, and if you go prodding it with a metal screwdriver, sure as eggs is eggs you'll break it. If you can't afford 50p for a plastic trim tool, make yourself one by filing down that favourite plastic knitting needle of Granny's.

# SURVEILLANCE



The safest thing is to set the core 1mm below the top of the coil former (roughly, that is — don't measure it!) and tune the radio. With the bug anywhere in the same room, you'll get a loud feedback whistle as soon as you hit the right frequency. (If you get a feedback whistle without your bug connected up, I should start wondering who has planted a bug on you.) That's all there is to be done, unless the bug is transmitting in a crowded part of the band: you can raise the frequency by moving the core higher, or lower it by screwing the core deeper into the former.

If there is no sign of life from the bug, it's five pounds to a bag of wire clippings that you've shorted out some tracks. Check the underside of the PCB carefully and make absolutely sure that there's no stray solder blobs and that the solder hasn't wandered from one pad to the one next door. Clean off the board with some iso-propanol and scratch off any bits of dross that may remain.

The other possibility is that, because of component tolerances, the bug isn't quite hitting the FM waveband. Tune your radio to the middle of the band and (carefully) adjust the core of the bug's tuning coil until you get the whistle.

For test purposes, and indeed for transmitting to your car outside or for some way down the street, an antenna consisting of a component lead offcut will be fine. You'll be surprised how far it will carry with an antenna less than an inch long. For the best range though, you really need an antenna of about 2 1/2 ft in length. And it must be kept straight. A length of connecting wire, insulated, will fit the bill admirably. Line of sight range is well over half a mile. This means what it says in that if you could, barring trees and walls of the house, actually see the transmitter from the receiver, that's the range you'll get. If there's a chuffin' great hill in the way, it's asking a bit much to expect the signal to go straight through it. The same goes with streets and streets of houses: the more there is in the way the less the range will be, so choose your listening post with this in mind.

## Telephone Bug

This one is connected to the victim's telephone line. Snip a wire, splice two connections and it's in. Once

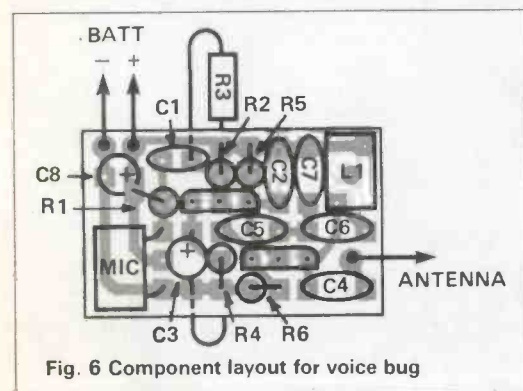


Fig. 6 Component layout for voice bug

installed it remains alert and watchful but completely silent between calls. As soon as the handset is picked up, it senses the change and begins transmission of both sides of the conversation, drawing its power from the line. An evil little device.

The circuit is shown in Fig. 7. R1 drops sufficient voltage to allow the circuit to operate, without affecting the working of the telephone. The bridge rectifier means you don't have to bother about which way round to connect it. Either way around, and to either line. The job's over in a matter of seconds.

The transmitting section is just the same as for the voice bug. If you've got a good circuit, why change it? The range, as before, is a few hundred yards with a 1inch antenna, and half a mile or more with a 2 1/2 ft straight aerial.

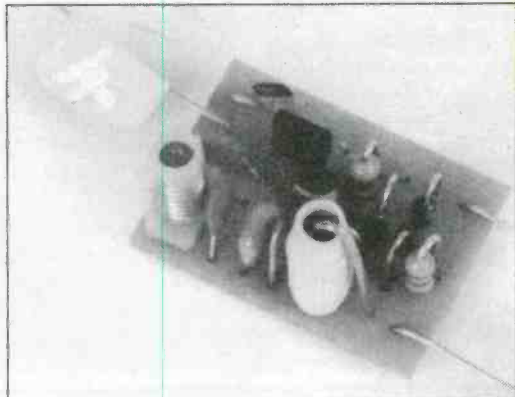
The component layout is shown in Fig. 8, and yet again I'll say: be careful not to short out adjacent tracks. Check afterwards, and check again. The track side link should be put on last of all. OK, I admit it, another boob. You wouldn't believe what a rush it's been to get four whole projects ready for you, so I hope you'll forgive the mistake.

Connecting this little darling to a telephone line is against the law, so of course you won't do it. But you may be interested to know how the bad people who don't give a fig for the law might go about testing the circuit. First they would take off the lid of the junction box where the telephone wires enter the house. Inside they would find the two wires connected, depending on the age of the installation, either to screw terminals or to an IDC connector block. In either case they'd remove one of the wires, slip one of the bug's input leads into the connector (or screw it to the terminal) and splice the other to the loose wire. Next they would lift the telephone handset to get the dialling tone, then pop over to the radio and tune it across the band until they heard that very tone reproduced on the radio. If the ferrite core needed adjustment to bring the transmitter frequency within the FM broadcast band, they'd never ever use a metal tool. Rumour has it they'd file down a plastic knitting needle to make themselves a little trim tool, and I have heard tell they'd be ever so careful not to break the core.

So there you have it, folks. Your home spy kit. Bug anyone you like, as long as it's not me. Please note that using these circuits contravenes the Wireless Telegraph act and quite possibly privacy laws as well, and if you find two sour faced gentlemen listening to a radio outside your house, my advice is to flush them down the loo pretty damn quick. The bugs, that is. You'll find yourself in court for assault if you try flushing home office employees.

Using the telephone bug will also get you into trouble with British Telecom, and believe me if they come knocking on your door they will be quite humourless about it. You'll be up in court, and that's that.

We share this world, and even our hobby, with



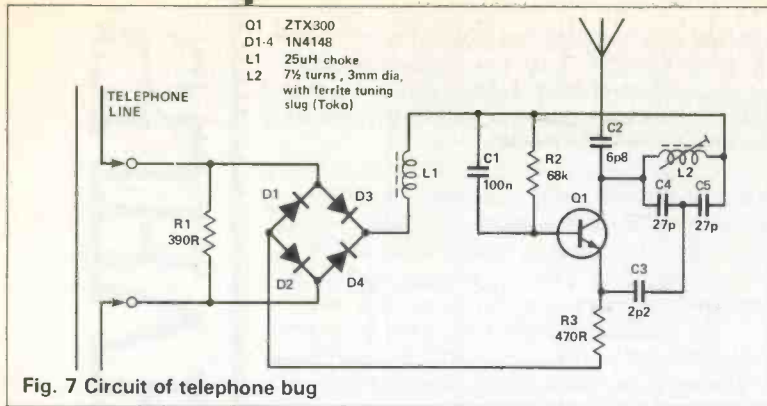


Fig. 7 Circuit of telephone bug

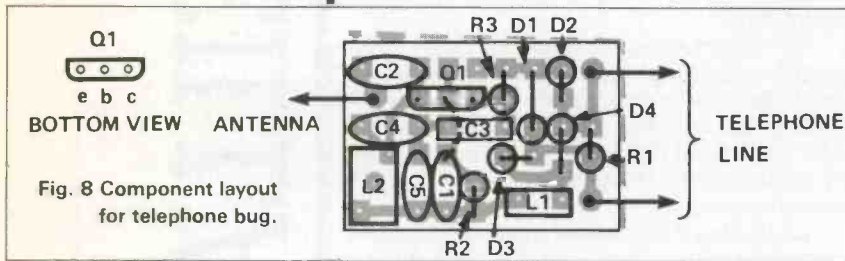


Fig. 8 Component layout for telephone bug.

certain worthless individuals whose first instincts if they find themselves in trouble is to find somebody else to blame. 'It's not my fault' they whine. 'ETI told me to do it. They shouldn't publish things like that if it's against the law'. Rubbish. We treat you all as responsible people. You have the circuits, you also have the warning. It's your choice alone whether to bin the board or build projects. So be good, be careful, and have fun with the circuits in any way you choose.

## BUYLINES

OK, so you missed out on the free components. Pencil and paper ready? Then this is what you do. Specialist Semiconductors, bless 'em, have taken it upon themselves to cove out the remaining bags, so you either phone them on (0600) 3715, or write to them at Founders House, Redbrook, Monmouth. Gwent. As long as you get in touch before they're all gone, the components will come zipping through the post to you forthwith. While you're on the phone, ask them to send along the list of components for the projects - they can supply all the specified parts.

If these projects give you a taste for RF circuits, a useful catalogue for your shelves can be had from Cirkit. They stock all kinds of RF gear, components and kits. Contact them on (0992) 444111, or write to them at Park Lane, Broxbourne, Herts.

## PARTS LIST

### FREE BUG PROJECT

R1 220k  
R2 220R  
C1 2n2  
C2 47p  
C3 27p  
Q1 Free transistor (or ZTX300)  
L1 On free PCB

Additional parts: crystal microphone insert, battery connector, PP3 battery, length of wire for antenna.

### CORDLESS GUITAR

#### RESISTORS

R1 100k  
R2 33k  
R3 12k  
R4 3k3  
R5 6k8  
R6 470R

#### CAPACITORS

C1 2u2 tant or min. elect.  
C2 2u2 tant or min. elect.  
C3 2n2 ceramic  
C4 2p2 ceramic  
C5 27p ceramic  
C6 6p8 ceramic

#### SEMICONDUCTORS

Q1 ZTX300  
Q2 ZTX300  
D1 MV2110

#### MISCELLANEOUS

L1 25uH choke  
L2 7½ turns, 3mm dia., with ferrite tuning slug. Toko coil used in prototype.

Battery connector, PP3 battery, length of wire for antenna, free PCB.

### VOICE BUG

#### RESISTORS

R1 12k  
R2 100k  
R3 33k  
R4 3k3  
R5 11k

R6 470R

#### CAPACITORS

C1 100n ceramic  
C2 2n2 ceramic  
C3 2u2 tant or min. elect.  
C4 6p8 ceramic  
C6 27p ceramic  
C7 27p ceramic  
C8 47u tant or min. elect

#### SEMICONDUCTORS

Q1 ZTX300  
Q2 ZTX300

#### MISCELLANEOUS

L1 7½ turns, 3mm dia., with ferrite tuning slug. Toko coil used in prototype  
MIC1 Electret microphone insert  
Battery connector, PP3 battery, length of wire for antenna, free PCB.

### TELEPHONE BUG

#### RESISTORS

R1 390R  
R2 68k  
R3 470R

#### CAPACITORS

C1 100n ceramic  
C2 6p8  
C3 2p2  
C4 27p  
C5 27p

#### SEMICONDUCTORS

Q1 ZTX300  
Q2 ZTX300  
D1-4 1N4148

#### MISCELLANEOUS

L1 25uH choke  
L2 Toko 3mm coil with tuning slug.  
Length of wire for antenna.  
Free PCB

## THE RTC MONITOR II

100 WATT SPEAKER KIT £60.00 +£3.50 P&P (pair)  
RESPONSE: 55Hz-20kHz

BASS POLYMER CONE D: 22cm  
DOME TWEETER: 14mm

OVERALL SIZE  
(HWD): 382,252,204mm

RECOMMENDED AMP POWER:  
10-100 watts per channel

The performance standard achieved in this compact design is distinctively superior to anything else available at the price. The drive units used are of sophisticated design and have been carefully integrated with a Complex Crossover.

Stereo performance is exceptionally good with a well focussed sound stage and sharp resolution of detail. Distortion throughout the frequency range is low even at quite high power input and this gives a great sense of dynamic range and openness especially when used in bi-wired mode.

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CROSSOVER KIT. To build 2 sets of crossovers £11+£1.75 post. (Featured in *Everyday Electronics*—May 1989 issue). Reprint Free with Kits



## AMPHONIC 125+125 POWER AMPLIFIER



125 watt per channel stereo power amplifier with independent volume controls, professional 19" rack mount and silent running cooling fan for extra reliability.

Output power ..... 125W RMS max. per channel  
Output impedance ..... 4 to 16 ohms  
(max. power into 4 ohms)

Sensitivity ..... 450V at 22K ohms  
Protection ..... Electronic short-circuit and fuses  
Power ..... 220-240V a.c. 50Hz  
Chassis dim ..... 435x125x280mm

£124.99 + £7.00 p&p

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As new condition but have been returned by customers or shops, so they may need some attention. Hence the price of only £8.00 each. Order six of these units and you get the seventh one free. Postage £2.90

## LCD DIGITAL MULTI TEST METERS

AC/DC volts resistance and DC amps. Most of these units are new but have been returned or rejected by the store and sold with all faults at £11.00 each. Postage £1. (Made by Ross Electronics.)

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4 1/2" 100W HI-FI MID RANGE 1" VOICE COIL, PAPER CONED AND DOPED CAMBRIC EDGE FITTED WITH A 3 1/2" MAGNET. 6Ω IMPEDANCE £5.33

4 1/2" HI-FI TWEETER 3/4" VOICE COIL, 1 1/4" CONE WITH FOAM EDGE, 2 3/4" MAGNET, 6Ω IMPEDANCE £6.33

POSTAGE £4.70 PER ORDER

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BP012	2	6 1/2" Speaker 4Ω 10 watt
BP013	3	8" x 5" Speaker 4Ω 6 watt made by E.M.I.
BP015B	1	30 watt, dome tweeter. Size 90x66mil JAPAN made
BP016	6	2200µf can type Electrolytic 25V d.c. computer grade made in UK by PHILIPS
BP017	3	33000µf 16V d.c. electrolytic high quality computer grade UK made
BP018	3	2000µf 50V d.c. electrolytic high quality computer grade made in USA
BP019	20	20 ceramic trimmers
BP020	4	Tuning capacitors, 2 gang dielectric a.m. type
BP021	10	3 position, 8 tag slide switch 3 amp rated 125V a.c. made in USA
BP022	5	Push-button switches, push on push off, 2 pole change over. PC mount JAPAN made
BP023	6	2 pole 2 way rotary switch
BP024	2	Right angle, PCB mounting rotary switch, 4 pole, 3 way rotary switch UK made by LORLIN
BP025	4	3 pole, 3 way miniature rotary switch with one extra position off (open frame YAXLEY type)
BP026	4	4 pole, 2 way rotary switch UK made by LORLIN
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BP028	10	Slide potentiometers (popular values)
BP029	6	Stereo rotary potentiometers
BP030	2	100k wire wound double precision potentiometers UK made
BP031	6	Single 100k multitune pots, ideal for varicap tuners UK made by PHILIPS
BP032	4	UHF varicap tuner heads, unboxed and untested UK made by PHILIPS
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BP033A	4	6" x 3/4" High grade Ferrite rod. U.K. made.
BP034	3	AM IF modules with diagram UK made by PHILIPS
BP034A	2	AM-FM tuner head modules. UK made by MULLARD
BP034B	1	Hi-Fi stereo pre-amp module inputs for CD, tuner tape, magnetic cartridge with diagram. UK made by MULLARD
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BP039	6	Double phono sockets, Paxolin mounted
BP041	3	2.8m lengths of 3 core 5 amp mains flex
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BP043	30	4V miniature bulbs, wire ended, new untested
BP044	2	Sonotone stereo crystal cartridge with 78 and LP styli JAPAN made
BP045A	2	Mono Cassette Record and play heads. (Japan Made)
BP046	4	6-0-6 4VA mains transformers, P.C. mount UK made
BP047	1	24V 750mA mains power supply. Brand new boxed UK made by MULLARD
BP049	10	OC44 transistors. Remove paint from top and it becomes a photo-electric cell (or P12) UK made by MULLARD
BP050	30	Low signal transistors n.p.n., p.n.p. types
BP051	6	14 watt output transistors. 3 complimentary pairs in T066 case (ideal replacement for AD161 and 162s)
BP052A	1	Tape deck pre-amp IC with record/replay switching No LM1818 with diagram
BP053	5	5 watt audio ICs. No TBA800 (ATEZ)
BP054	10	Motor speed control ICs, as used with most cassette and record player motors
BP055	1	Digital DVM meter I.C. made by PLESSEY as used by THANDAR with diagram
BP056	4	7 segment 0.3 LED display (R.E.D.)
BP057	8	Bridge rectifiers, 1 amp, 24V
BP058	200	Assorted carbon resistors
BP059	1	Power supply PCB with 30V 4V/A transformer. MC7818CT IC & bridge rectifier. Size 4" x 2 3/4"
BP060	1	Transcription record player motor 1500rpm 240V a.c.
BP061	5	6.35mm Mono jack plugs
BP063	5	6.35mm stereo switched jack sockets
BP064	12	Coax chassis mount sockets
BP065	1	3mtr Euro-mains lead with a matching chassis socket

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Size (H.W.D.) 75x400x195mm

Kit enclosed: case, P.C.B., all components, scale and knobs £36.80. post £3.50

(Featured project in *Everyday Electronics* April 1989 issue). Reprint Free with kit.

## TV SOUND TUNER



In the cut-throat world of consumer electronics, one of the questions designers apparently ponder over is "Will anyone notice if we save money by chopping this out?" In the domestic TV set, one of the first casualties seems to be the sound quality. Small speakers and no tone controls are quite common and that really is quite sad, as the TV companies do their best to transmit the highest quality sound. Given this background a compact independent TV tuner that connects direct to your Hi-Fi is a must for quality reproduction. The unit is mains operated. This TV SOUND TUNER offers full UHF coverage with 5 pre-selected tuning controls. It can also be used in conjunction with your video recorder.

£29.50 +£2.50 p&p

## As above but with built-in stereo headphone amplifier for the hard of hearing

You can tune into the TV channel you want while still receiving the picture on your TV set. In fact it is rather like a second television, but without the screen. So that the ordinary TV can be placed for everyone to see, and the volume on it can be comfortable for others, while the sound tuner can be placed where you can control it. You will need to plug in one of your own listening aids such as headphones or an induction loop to hear the sound. The tuner is mains operated, has 5 pre-selected tuning controls and can be used in conjunction with a video recorder.

Size: 270x192x65mm. £35.90 +£2.50 p&p

## TV SOUND TUNER KIT £11.50 +£1.30 P&P

All parts including Varicap tuner, mains transformer, PCB with IC's capacitors and coils etc., to build the unit illustrated above; without case and scale.

## SHURE HI-FI STEREO MAGNETIC CARTRIDGE

Fitted with an elliptical diamond stylus supplied with fitting kit and instructions. A good quality unit made to suit for well over twenty pounds due to scoop purchase, we are able to offer these at a fraction of the manufacturers price. All units are brand new and boxed. £7.20 each. If you order in multiples of five you get one free. Postage £1.30 (Made in U.S.A.)

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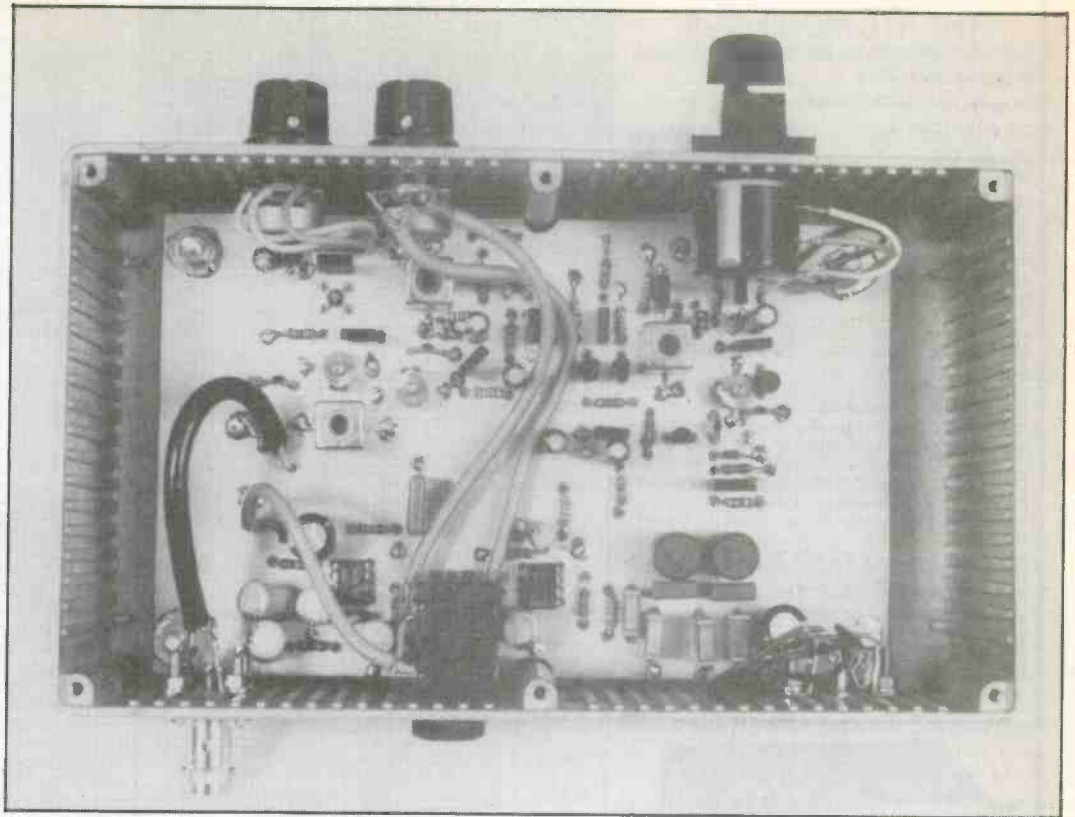
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David Silvester tunes in to the 20 metre amateur band

PROJECT



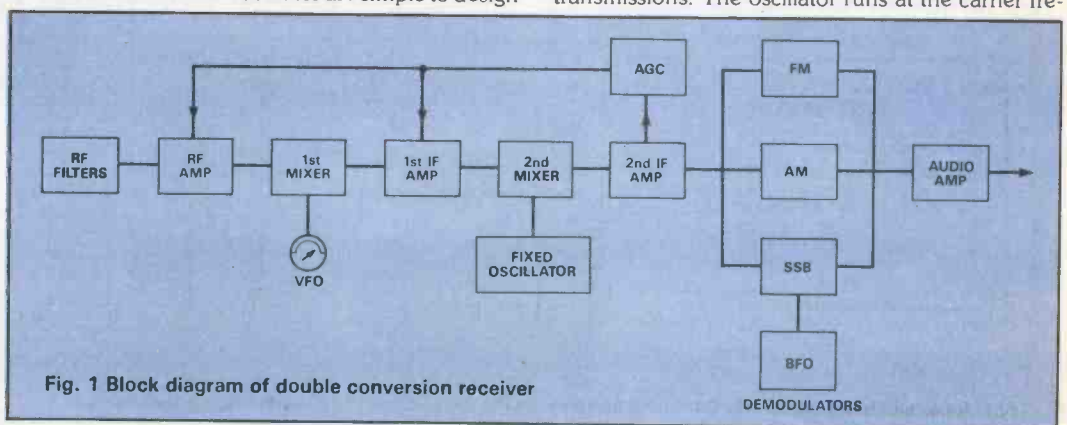
## TWENTY METRE RECEIVER

Single sideband (SSB) receivers are normally associated with high performance and can be rather expensive. However for the person newly interested in amateur radio or simply HF radio reception, the outlay of many hundreds of pounds on a good quality receiver may be too much for something that may turn out to be only of short term interest. If the listener is willing to build rather than buy, then a reasonable quality receiver using the direct conversion technique can be built for a few tens of pounds rather than hundreds. With an interest in construction and insufficient cash to go out and buy a transceiver the author decided to build a direct conversion receiver for the 20 metre amateur band as much to see what is possible using a simple circuit. The 20 metre band allows world-wide coverage at certain times and is open to interesting places all year round.

Direct conversion receivers are simple to design

and build, they have good sensitivity and are easy to use. The alternative of a tuned radio frequency receiver was eliminated as they are more difficult to use.

Commercial receivers use either double conversion techniques shown in Fig. 1 or the simpler single conversion type where the first IF amplifier, the second mixer and its oscillator are left out but high cost crystal filters are included to keep the bandpass within acceptable limits. The provision of three detectors for AM, FM and sidebands and either twin stable oscillators or crystal filters for bandwidth control increases the cost. Fig. 2 shows the direct conversion technique; there is one stable oscillator which actually runs at the same frequency as the signal being received. Filtration is carried out at AF where the use of an inductor/capacitor filter is easy to design and build. Direct conversion receivers are primarily designed for use with single sideband, carrier wave (CW), and morse transmissions. The oscillator runs at the carrier fre-



quency acting similarly to the beat frequency oscillator in a superheat receiver. However, with care the receiver will demodulate AM signals although the carrier causes a problem because detuning leaves a loud whistle in the headphones. The receiver will need to be set accurately to null this out. For all types of reception oscillator stability is of primary importance. To examine direct conversion let us look at an incoming upper sideband signal that would have had a 14.200MHz carrier if this were not removed prior to transmission (See Fig. 3a). In the direct conversion receiver, we mix the band of signal frequencies that have been transmitted with a stable signal of 14.200MHz. In the mixer, the sum and difference frequencies are generated and the difference frequency, an audio signal, is filtered out from the rest. The principals of reception are also true for lower sideband and CW signals. The signal will still be resolved. If the internal oscillator is only slightly away from the correct frequency, but the audio tone will be higher or lower depending on the difference.

When we start to look at the problems with direct conversion we must remember that we are talking about a radio receiver that costs a few pounds to build rather than many hundreds to buy. Consider the situation with a CW signal shown in Fig.3b. If the incoming signal is at 14.100MHz then the oscillator, set at either 14.099 or 14.101MHz, both differing from the incoming signal by 1kHz, will resolve the CW signal as a 1kHz audio tone. So when tuning across the band with a direct conversion receiver, the single CW signal will appear twice. This is one of the major problems concerning the direct conversion receiver.

With a single sideband signal an interesting effect occurs. Fig.3c shows an upper sideband signal with a missing carrier at 14.200MHz. If the receiver's oscillator runs at 14.200MHz then the radio signal is correctly resolved into an audio signal, but if the oscillator is set at 14.203MHz the original upper sideband signal is treated as a lower sideband signal by the mixer and the audio frequencies are inverted.

Consider two tones in the original voice signal and let these be 1kHz and 2kHz. Now after SSB conversion, the 1kHz tone is transmitted as 14.201MHz and the 2kHz tone as 14.202MHz. If by accident we reinsert the carrier at 14.203MHz, then the mixer takes the difference signal as the audio tone and the 14.202MHz signal comes out of the mixer as a 1kHz tone (14.203-14.202) with the 14.201 signal as a 2kHz tone. So the higher tones of the original signal become the lower tones of the incorrectly resolved AF. Luckily our ears are able to ignore the gibberish that this gives and allows us to hear the signal that would be correctly resolved by the 14.203MHz oscillator frequency. In many cases there is sufficient frequency gap between incoming signals so that the inverted AF tone problem causes little practical difficulty.

## Design Considerations

The block diagram for the radio is shown in Fig.2 An important design requirement is the stability of the single oscillator which in this case runs from 14.000 to 14.350MHz. This oscillator must be stable to within a few Hertz after a short warm-up period otherwise the user will forever be returning the radio. The oscillator needs to be settable to within about 100Hz so that the oscillator control can be calibrated in Megahertz otherwise a conversion chart can be drawn up.

Stability will be lost if long wires are used from oscillator is tuning capacitor so an alternative is to use variable capacitance diode pair as the frequency controlling element in the design. The varicap control is carried out by voltage derived from a ten turn potentiometer. Design is also simplified by the use of ready made coils and they are all available commercially as part of the Toko range.

## Construction

The whole circuit except for the three potentiometers is mounted on a single PCB, shown in Fig.6. This board has its lower surface etched to form the track pattern and the upper surface left as a solid ground plane. When making the board, the lower surface is exposed, developed and etched as usual but the upper surface is covered to prevent any removal of the copper layer. In the final stage of board production, holes are drilled through all of the pads on the lower surface; a 1mm drill seems to be the best size for this operation. There are four through board connections shown in Fig.6 by the circled crosses, where the upper ground plane must be left and lastly all of the remaining holes on the upper surface have a 1mm ring of the copper film removed from around them so that the component wires could pass through without shorting to ground. A 1/8 inch drill mounted in a handle can be for this. In many cases the components have one end connected to the upper surface of the board and these components have the end connected to the upper ground plane marked with a cross in Fig.6. Some coil pins and the dual in line ICs need to be connected to ground and in these cases the pin is soldered to a pad on the lower surface of the board and then one of the through board con-

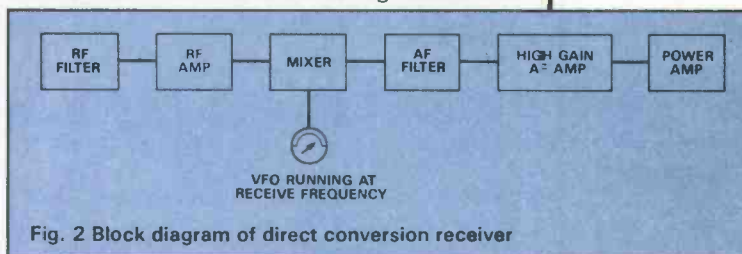


Fig. 2 Block diagram of direct conversion receiver

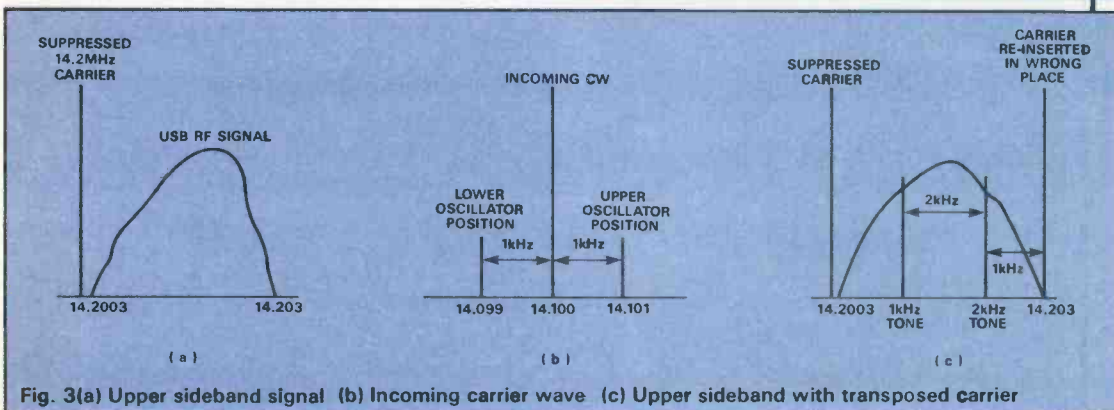


Fig. 3(a) Upper sideband signal (b) Incoming carrier wave (c) Upper sideband with transposed carrier

# PROJECT

# TUTOR

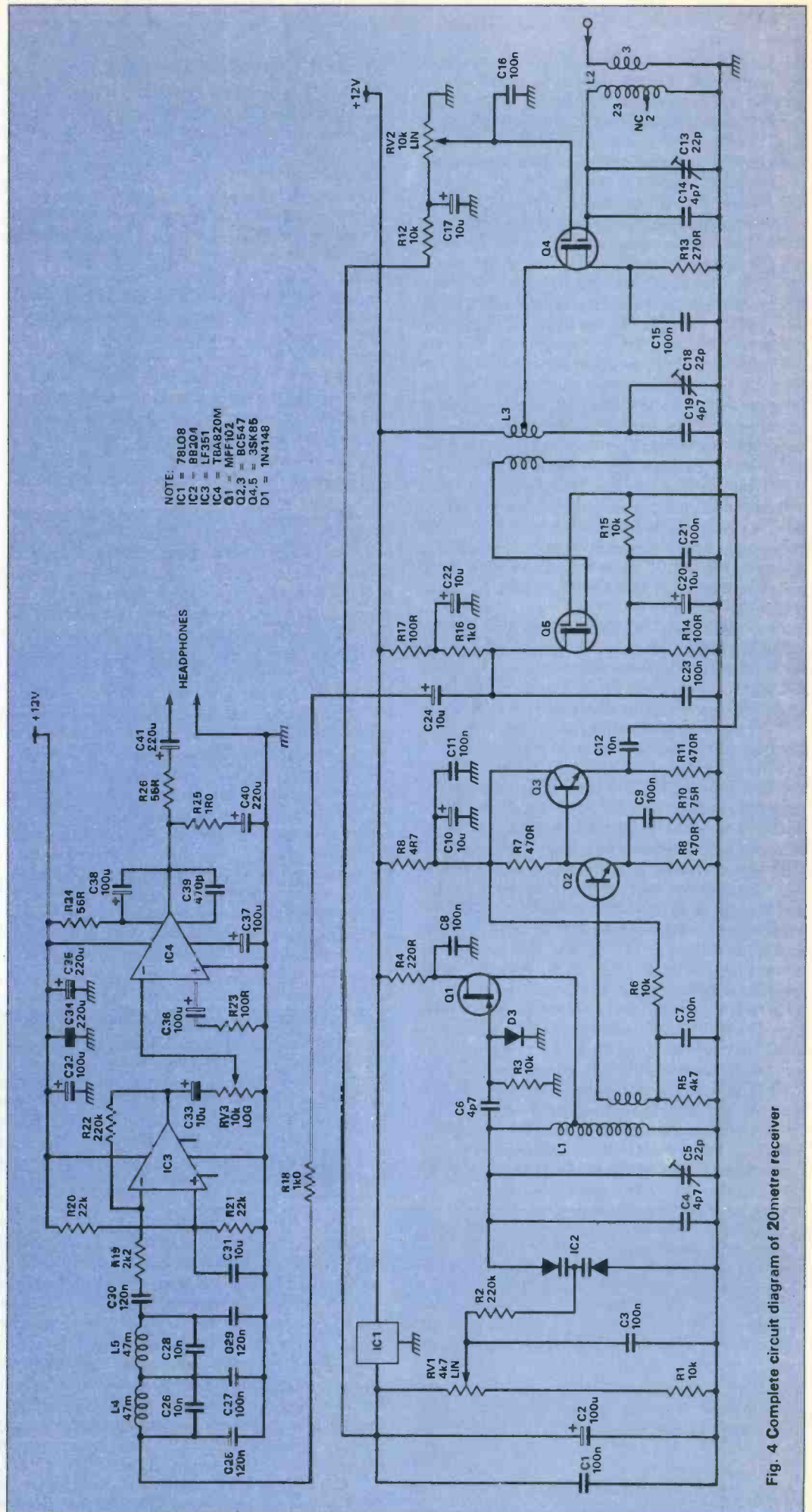


Fig. 4 Complete circuit diagram of 20metre receiver



Fig.4 shows the full circuit diagram for the radio. The oscillator is a standard Clapp oscillator. Diode D1 and the resistor R3 provide gate bias for the FET Q1. The tuned circuit consists of the inductance of L1, the parallel capacitance of C4/C5, and the varicap diode pair IC2. Feedback to maintain oscillation is taken from a tap on the primary coil of the inductor. The output from the oscillator is from a small secondary coil so that the following buffer only lightly loads the oscillator. During development an MPF102, a BP245 and a 2SK55 were tried in the position Q1. In all cases the output was similar so any of these and possibly many other FETs may be used, although some care will need to be taken to assure that the FET leads are connected correctly as the pinouts do vary between types.

The capacitance of the varicap diode pair needs only to vary over about 1pF to obtain the full input frequency range of the receiver. If a single varicap is used then a problem occurs because its capacitance varies as the oscillator operates, since the varicaps capacitance varies as its bias varies. To overcome this, the oscillator uses a back to back common cathode varicap pair in a single TO92 package, in which as one diode loses bias, the other receives extra and the capacitance across the anodes remains approximately stable. The other problems is that both diodes must be held in reverse bias even though the anode voltage at the upper end connected to the coil will be varying at 14MHz. This is overcome by making the minimum central bias voltage higher than the peak RF voltage at the top end of the coil. The bias voltage is derived from the 8V regulator - IC1 and the potential divider - RV1 and R1. This voltage can never be less than 4V and allows a 4.6 peak RF voltage.

The ten turn pot, although costly, was chosen because an indicating dial can be used with this type showing receiver frequency.

Capacitors C1, C2, and C3 provide stability for the tuning voltage and prevent the oscillator signal feeding back into the voltage regulator IC1. During operation, no current flows out of the varicap except for leakage currents, so resistor R2 provides an RF block whilst passing the varicap DC bias voltage. R4 and C8 isolate the FETs drain from the 12V power supply as feedback of RF may affect the other RF circuits.

The second stage is a buffer amplifier formed around Q2 and Q3. This brings the signal available at the transformer tap up to about 5 volts peak to peak to drive the gate of the dual gate mixer transistor Q5. Buffer Q2 provides the gain, controlled by the ratio of R7 to R10, with Q3 as an emitter follower. The output RF voltage passes to the mixer via C12. R8, C10 and C11 are the stage isolation components. R5, R6 and C7 provide the bias voltage for the stage.

The RF circuit consists of the 14MHz tuned amplifier and a mixer. The RF amplifier has been included to prevent the possibility of the oscillator signal feeding back radiation to the antenna. Both circuits use dual gate MOSFET transistors and care must be taken in soldering the transistor into the circuit. The RF amplifier Q4 is connected to the antenna via the tuned transformer L2. R13 sets the bias for Q4's source whilst C15 holds the source at AC ground. The tuned circuit using L3, C18 and C19 forms the load for the amplifier.

The second gate of Q4 is connected to a variable bias voltage derived from the same 8V supply as the feed for the oscillator tuning. Varying the bias voltage alters the transconductance of the MOSFET and this alters the gain of the amplifier stage. This gain control is used to prevent overload of the mixer and the first AF amplifier, when strong signals are received.

The second winding on L3 passes the amplified antenna signal to gate 1 of the mixer stage and also provides its dc bias. In the mixer the dc bias voltage for gate 2 is held at the same voltage as the source through R15. A series of frequencies are generated but only the audio difference frequency is used. R16 is the load for the mixer with the usual stage isolating components R17 and C22. The capacitor C23 shorts any of the mixer's RF signals to ground, and C24 and R18 pass the audio signal to the AF filter.

The AF filter consists of L4, L5, and C25 to C29. As can be seen in Fig.5, this is a low pass filter with a high cut off rate above 3kHz to attenuate signals outside the normal SSB range. This does lead to the possibility of receiving more than one CW signal if they are closely spaced but it was felt that most users would be listening to SSB

transmissions. In any case a communications receiver will need to be fitted with high cost narrow band filters to resolve this problem and the whole idea for the direct conversion receiver was low cost. C30 working into the 2k2 input impedance of the first AF amplifier gives the low cut-off of 300Hz but due to the low rate of attenuation with frequency of the resistor capacitor filter, this cut-off point is adequate for SSB reception.

The AF amplifier has two stages, a simple inverting op-amp biased for use with a single power supply and a dedicated low power amplifier. The first stage is a standard circuit with an input impedance of 2k2 ohms defined by R19 and a voltage gain of 100 (equivalent to 20dB) set by the feedback resistor R22. As the receiver only has a single power supply of 12 volts, the non-inverting input to the op-amp has to be held at about 6V to put the op-amp into its linear operating region. This voltage is provided by R20 and R21 with C31 to remove any AC from the op-amp input. Capacitor C33 removes the dc offset at the output of IC3 and passes the AF signal to the volume control RV3 and on to the power amplifier IC4. This stage has a voltage gain of 35dB and a theoretical power output of 2 watts. Using headphones, the series load resistor R26 cuts down the volume, and also prevents damage to the power amplifier chip if the output plug is accidentally shorted out.

With stereo headphones, the two earpieces are connected in parallel to give a load impedance of 4 ohms. C41 isolates the DC on the output of the power amplifier IC from the headphones.

To ensure stability, all of the ICs in the AF amplifier have capacitors across their supply pins and the input has a noise rejection capacitor C37.

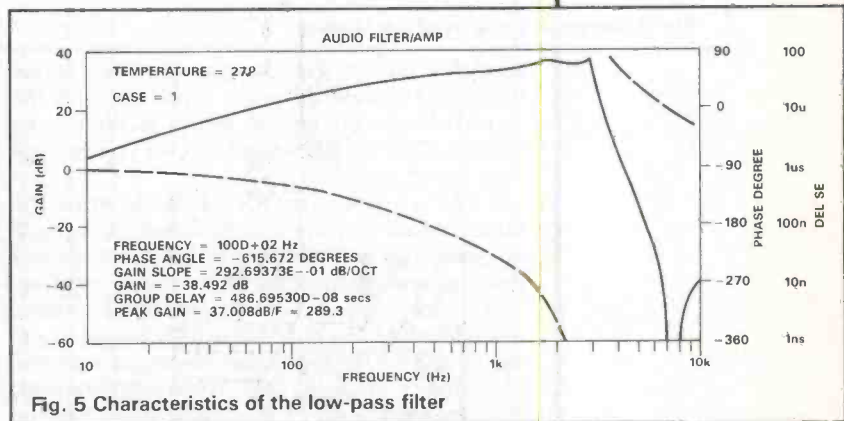


Fig. 5 Characteristics of the low-pass filter

nection completes the circuit. The transformer cans are also connected to the groundplane by bending the tabs provided, out to the side and soldering to the upper surface. The ground plane is a good conductor of heat as well as electricity and a fairly large soldering iron bit needs to be used if joints to the ground plane are to be successful. If a large soldering iron is used to solder the small pads on the lower surface, great care must be taken to avoid damaging them.

Actual construction is possibly best carried out in the following order. Firstly locate the position for the three metal can transformers, these are easy to find due to the distinctive five pin layout, and the position for the two ICs, again easy to find from the 8 pin layout. Cut back the upper groundplane around the transformer and IC holes, fold back the tabs on the transformer cans and tin the tabs. Insert the transformers, solder the pins and solder the tabs to the groundplane. Locate the position for the four through board connections, push pins or short pieces of wire through to make the connections and solder to both the upper groundplane and the lower track. Then cut back the groundplane around all the remaining holes.

Care needs to be exercised when building the PCB as the components are tightly packed in some

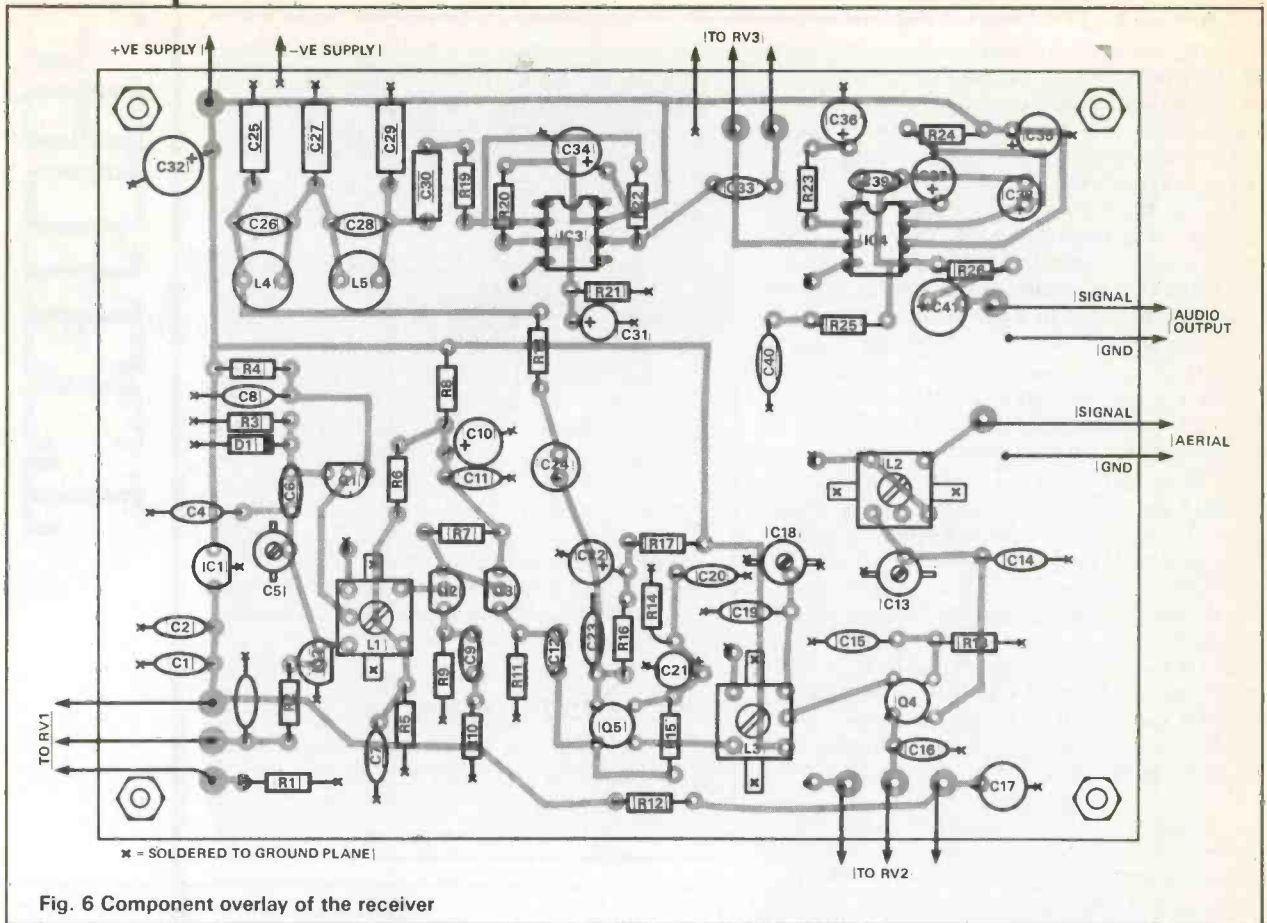


Fig. 6 Component overlay of the receiver

# PROJECT

areas. Construction should cause no problems but the usual care should be taken especially over the connections to the ground planes as there is no indication of the orientation for these components from the holes alone.

The two dual-in-line ICs were soldered into the board instead of using sockets. Board mounting is advantageous with inexpensive ICs like these and provides some heatsinking for the power amplifier. The only components not on the board are the three potentiometers. The pots RV1 and RV2 only carry dc signals and the RF pickup that may occur is shorted to ground on the board itself. These potentiometers are connected to the PCB by single strand hookup wire. The third pot, RV3 carries AF signals at fairly high amplitude and in an attempt to reduce pickup this is connected to the PCB with audio coax cable. At the PCB end of the connection both of the screens for the coax signal cables are connected to the upper ground plane. At the potentiometer, the coax from the first stage amplifier IC3 via C33 has the core connected to one end of the pot and the screen is connected to the other end of the pot to give the ground connection. The AF return wire uses just the core of the coax, the screen is cut back and covered with tape to prevent a ground loop forming.

The antenna connection uses a short length of UR43 or similar 50 ohm RF coax to prevent pickup from the oscillator, whilst the audio output uses another piece of audio coax. In all cases where a wire leaves the board the central conductor passes through the board and is soldered to a pad on the lower surface, and the outer conductor is soldered to the upper surface of the board. It is best to split the screen of the RF coax into two tails and attach them to two tags fitted to the coax socket's mounting bolts. The routing of the off board connections are not critical although it is advantageous to route the antenna input away from the oscillator.

The board, pots and input sockets for the

antenna, the 12V power supply, and the headphone socket are all fixed into an aluminium box. A circular area around each mounting hole on the board needs to be solder tinned to ensure that the ground plane securely connects to the case via the mounting bolts and metallic stand-offs.

The live tracks on the under-side becomes sandwiched between the box and the ground plane although strict attention must be paid to ensure that none of the lower surface connections touch the box. The pots are connected so that a clockwise rotation of the knob increases frequency or audio output. The clockwise end of RV1 connects to the pad going to C1 and C2, the clockwise end of RV2 to the pad joining R12 and C17 and the clockwise end of RV3 to the pad to C33, otherwise the controls will not work in the expected manner and the rig will be difficult to use.

The choice of audio socket will depend on the plug fitted to the headphones. Rather than replace this plug a mating socket of the correct size can be used, but the two terminals that carry the different signals in stereo operation need to be connected together at the socket.

The 12V input may be either by way of wires and a grommet or by one of the power plugs, depending on the constructors preference.

Two types of dial for the ten turn pot are suitable, either the round dial scaled from 0 to 100 and a number in a window which varies between 0 and 9, or a larger dial mechanism with a direct read-out. Round dial types have large control knobs which ease the tuning but are more complicated to read. Direct read-out types have a smaller tuning knob but are easier to read and reset to a specified frequency.

## Aligning the Rig

The ease of setting up the rig depends on the amount of equipment available. The receiver is designed to

work from a 12V power pack normally intended for powering CB and low power amateur rigs with an actual output voltage of around 13.6V. Although the aluminium box housing the receiver is a good electrical screen, it does not give any magnetic shielding and the magnetic field of the mains transformer in the 12V power supply can couple to the two inductors L4 and L5 giving a very distorted audio output. The separation only needs to be a few inches with the PSU on the side away from the inductors.

All three of the variable capacitors C5, C13 and C18 are initially set to a central position and the potentiometer RV1 is set so that the voltage at the end of R2 is 8V. This should be at the fully clockwise position if the pot has been installed correctly and this equates to an oscillator frequency of 14.4MHz. If an oscilloscope is available connect this to the emitter of Q3, then adjust the core of L1 until the peak to peak voltage at the emitter is 5V. Ignore frequency at this stage. Alternatively a digital voltmeter with an RF probe accessory can be used and the reading set to 5V as before.

A digital frequency meter is helpful in setting the frequency range of the oscillator, but this can be carried out using another receiver or by using a calibration signal from a crystal oscillator. Check that the oscillator can be set to cover the range 14.0 to 14.4MHz which covers the 20 metre amateur band and calibrate the read-out with the dial on the ten turn pot.

If no scope or DVM is available, the core of L1 can be set to the correct frequency with C5 left in the central position. The oscillator output will be sufficiently close for most users.

Once the oscillator is set, the rest of tuning amounts to adjusting the variable capacitors for the maximum audio output of a weak input to the antenna socket. This may be an off air signal or from a signal generator or grid dip oscillator.

True alignment and calibration needs the digital frequency meter, a crystal calibrator or the loan of a



communications receiver.

If the constructor is the member of a radio club then these will be available and members may be willing to help for the few minutes that calibration takes.

### Setting up the Antenna

A long wire can be strung from an upstairs window to a post at the end of the garden to represent the sort of antenna that the first time user may erect. This inverted L antenna needs a good ground connection that was provided by hammering a 3ft section of copper pipe into the ground. With this simple aerial and the direct conversion receiver, many countries in Europe and North and South America have been heard. Also, by early morning listening, Australia was added to the list. This should please amateurs or short wave listeners used to more sophisticated and more expensive receivers. More over this rig gains it's fascination not only because it is inexpensive, but because you built it yourself.

## PARTS LIST

### RESISTORS (all 1/4W, 1 or 5% carbon or metal film)

R1,3,6,12,15	10k
R2,22	220k
R4	220R
R5	4k7
R7,9,11	470R
R8	4R7
R10	75R
R13	270R
R14,17,23	100R
R16,18	1k0
R19	2k2
R20,21	22k
R24,26	56R
R25	1R0
RV1	4k7 lin 10 turn
RV2	10k lin
RV3	10k log

### CAPACITORS

C1,3,7,8,9,11,15,16,21,23,34	100n ceramic
C2,10,17,20,22,24,31,33	10µ radial electrolytic
C4,6,14,19	4p7 ceramic
C5,13,18	22p preset
C12,26,28	10n polyester
C25,29,30	120n polyester
C27	180n polyester
C32,36,37,38	100µ radial electrolytic

C35,40,41	220µ radial electrolytic
C39	470p ceramic

### SEMICONDUCTORS

IC1	78L08 8 volt regulator
IC2	BB204 dual varicap
IC3	LF351 or TL071 FET op-amp
IC4	TBA820M
Q1	MPF102 see text for alternatives
Q2,3	BC547 or any equivalent
Q4,5	3SK85 see text for alternatives
D1	1N4148 or equivalent

### INDUCTORS

L1	Toko KANK3334R
L2,3	Toko KANK3337R
L4,5	Toko 181LY473

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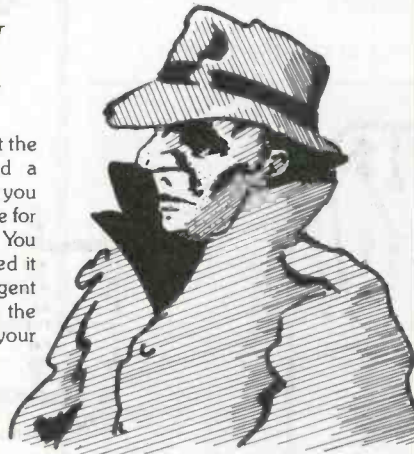
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# PCB FOIL PATTERNS

## In-car Power Supply (January 1989)

Fig. 3 shows the front view of the 317 regulator with the pin-outs reversed. The photograph, circuit and overlays are all correct showing the ledge at the front of the device.

## Audio Design MOSFET Amp (May 1989)

For home constructors of the power amp PCB (Fig. 8), the copper area connecting the negative of C7, C14 and R20 is a 0V #2 connection and should be linked to the 0V #2 copper area at the junction of C16 and C18+. Hart's kit PCB has a ground plane and no mod is necessary. Note that the preset at the bottom right of Fig. 8 takes the place of an external RV3 rheostat when bench testing and is not normally required. In Fig. 7 R14 is not shown — it should be in series in the negative feedback line between C8 and D3. Also in the parts list C20 is 100uF and R9 is 2k2.

## Bench Power Supply (May 1989)

In the Parts List, Q3,4 should be BC237 not BC307. The value in the circuit diagram is correct.

## How To MIDI A Piano (June 1989)

In Fig. 5 the connection from pin 19 of IC8 (MREQ) should go to pin 12 of IC7a, not pin 13 as shown. The component overlay is correct.

## MIDI Patchbay (July 1989)

Figure 3 shows Q1-6 as npn transistors. They should in fact be pnp and their emitters should be connected to R2-12 respectively (R12 is unlabelled). Although the bases are all connected together they should not be connected to their emitters.

## Reflex Action (July 1989)

Two lines in the listing on page 30 need amendment. Line 180 should read  
180 PRINT "Enclosure volume = ";vb:PRINT "tuned to";fb;"Hz":PRINT " -3db at "; f3:PRINT "Ripple = ";r;"db"

Line 280 should read  
 $280 \text{ I} = (2700 * \text{a}) / (\text{vb} * \text{fb} * 2) - 0.96 * (\text{a} * 0.5)$

## Chronoscope Revisited (September 1989)

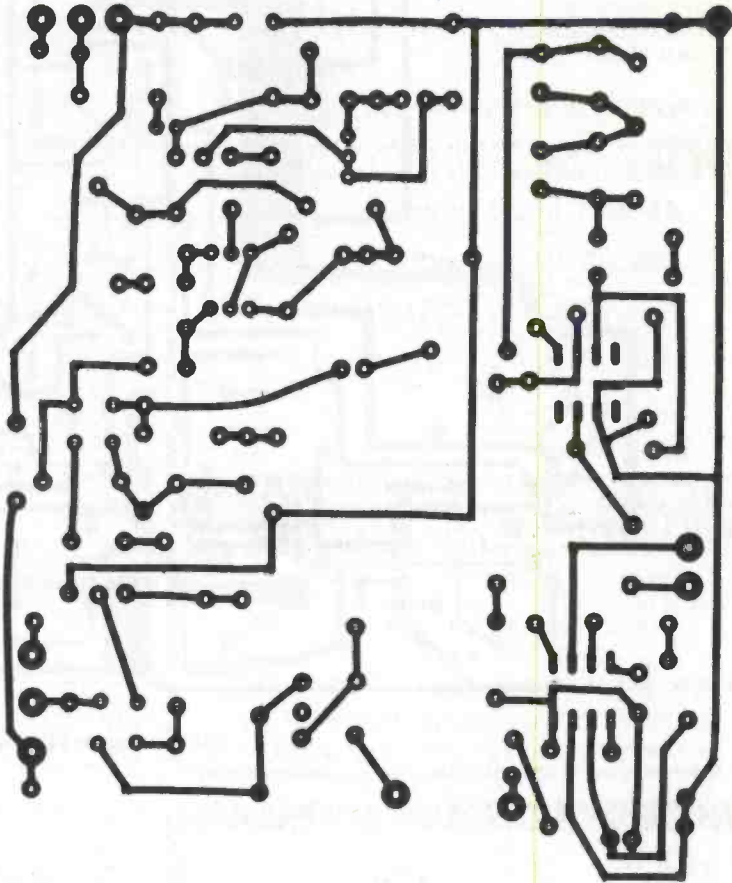
In the paragraph headed 'Connections', D10 should read LED8 (on the sensor board). Also in Fig. 2, IC10 is shown reversed. The notch should be next to R49.

## Field Power Supply (September 1989)

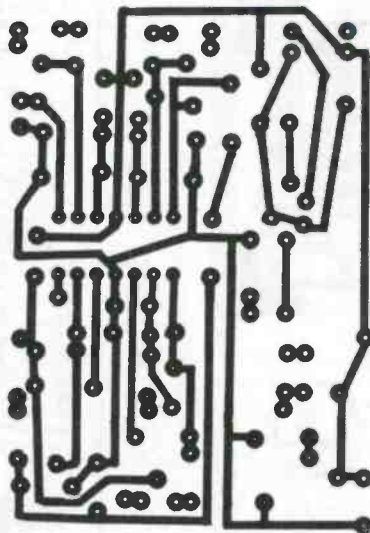
Figure 2 was printed with the artwork densities reversed, rendering a trifle tricky to interpret. It was reprinted together with a omitted col winding data on P62 of the October 1989 issue. A free photocopy is available from ETI Editorial on receipt of an SAE.

## Sound/Slide Synchroniser (December 1989)

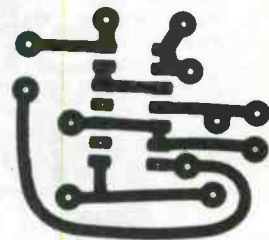
The incorrect foil was shown in the December issue for the Sound/Slide synchroniser, the correct foil is shown on this page.



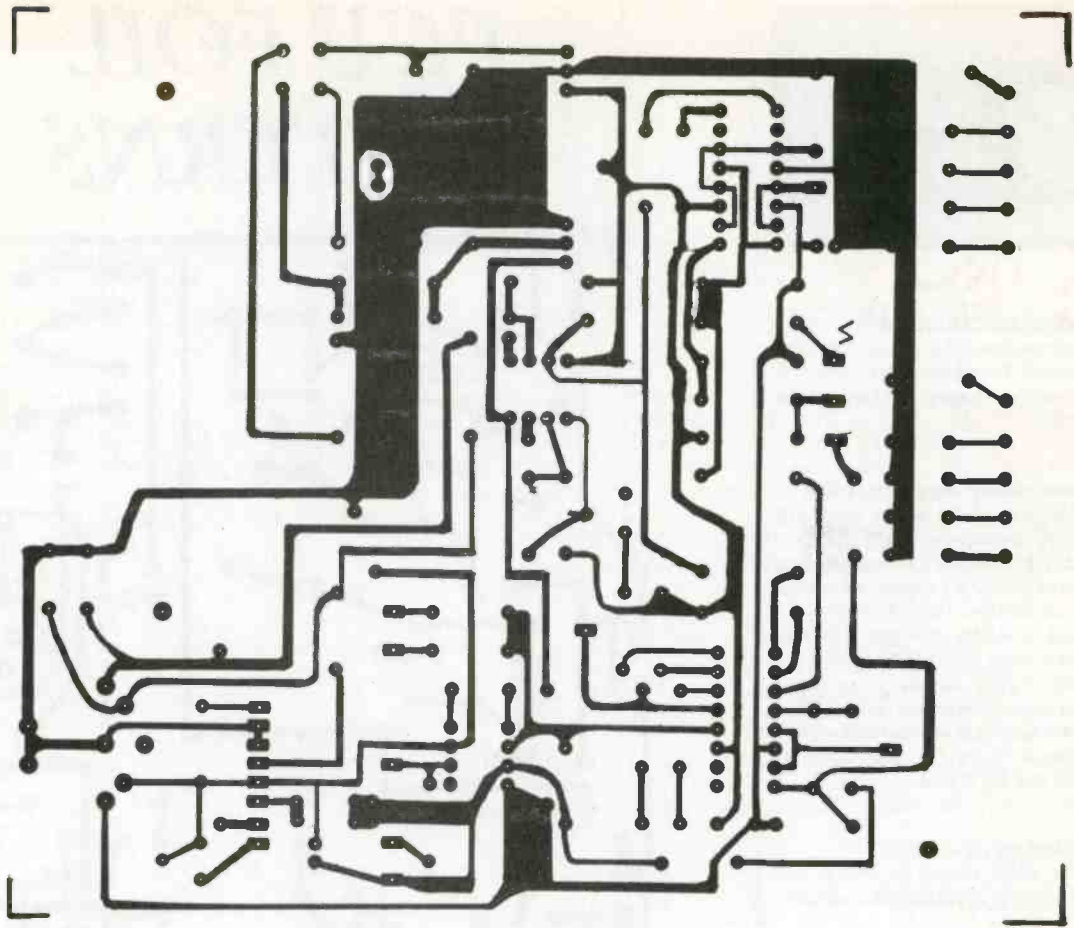
The 20 metre receiver foil



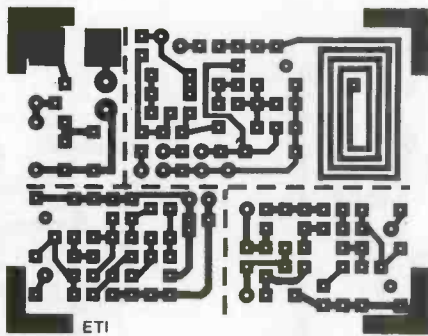
The correct Slide/Tape Sync board



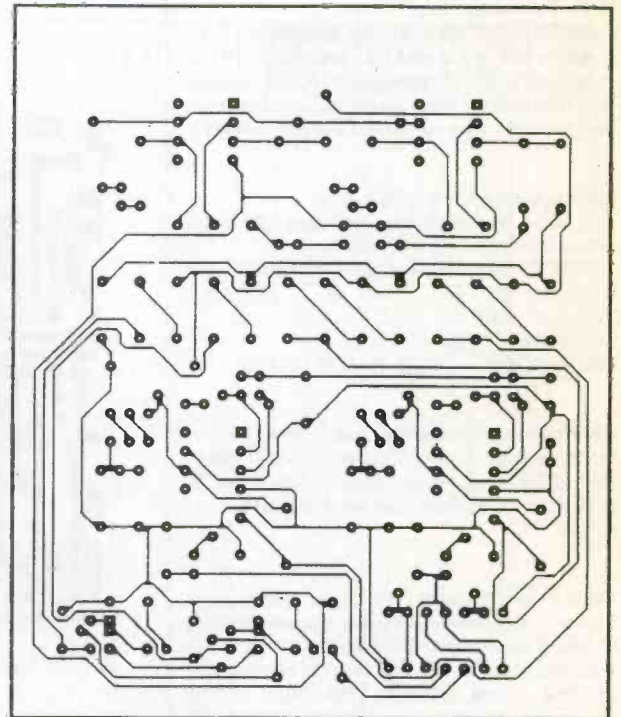
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# NEXT MONTH

In an astonishing display of self-promoting heroic generosity, next month's issue will contain not extra pages, not a weedy supplement, but a completely and utterly free full-size special edition of ETI — sat neatly inside the first.

This 68-page special will contain our selection of the finest and most popular projects to have featured in ETI during the halcyon days of 1989.

It includes such classics as:

- Pulsed Twin-loop Metal Locator**
- Micro Monitor Loudspeakers**
- Linsley Hood 80W MOSFET Amplifier**
- How To MIDI A Piano**
- Aerial Amplifier**
- Rev Rider**
- Digital Doorbell**
- Trembler Motion Detector**
- JLH Granny Aid**

And all these are just an added bonus to accompany an excellent main magazine. In the February issue we launch a major project — the ETI Cheapscope. This 20MHz dual-trace scope can be constructed at an astoundingly low cost. Full details next month.

Plus at last, the moment all you super-fi audiophiles have been waiting for — the ETI review of the Sage SuperMOS II amplifier modules, with complete critique and technical scrutiny.

We'll be running a major computer music talent

Please note that once the February issue sells out from the newsagent, back copies ordered will not include the Top Projects special. This will be available separately at normal cover price. Readers are advised to reserve their February copies with their newsagent.

## SPECIAL DOUBLE FEBRUARY ISSUE



competition with prizes including Casio's VZ-1 synth, studio time and MIDI-equipment kits.

There will be features on encryption and scrambling of television signals, a detailed look at surface mount technology, and a fascinating introduction to earth current signalling — wireless communication used in World War I trench warfare.

Together with news, readers' circuits and the projects that make us famous (an EPROM Emulator, a lighting controller and others), the February issue is a gem to be treasured.

## FEBRUARY ISSUE WITH FREE TOP PROJECTS SPECIAL — OUT FRIDAY JANUARY 5th

### ADVERTISERS' INDEX

AUDIO KITS .....	41	MERLIN SYSTEMS .....	60
BK ELECTRONICS .....	IFC	NATIONAL COMPONENT CLUB .....	60
CIRKIT HOLDINGS .....	22	NUMBER ONE SYSTEMS .....	17
CRICKLEWOOD ELECTRONICS .....	3, 41	PM COMPONENTS .....	31
DISPLAY ELECTRONICS .....	23	RADIO & TV COMPONENTS .....	53
ELECTROVALUE .....	33	SAGE AUDIO .....	11
EMINENCE .....	60	SHERWOOD DATA SYSTEMS .....	40
GREENBANK ELECTRONICS .....	41	STEWARTS OF READING .....	60
HART ELECTRONICS .....	22	SUMA DESIGNS .....	22
HENRYS AUDIO .....	3	TK ELECTRONICS .....	28
J&N BULL ELECTRICAL .....	32	TSIEN LTD .....	IBC
MAPLIN ELECTRONICS .....	OBC	WILMSLOW AUDIO .....	3
MATMOS LTD .....	11		

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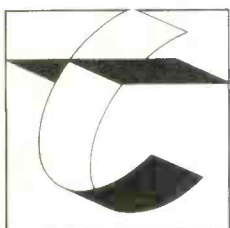
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