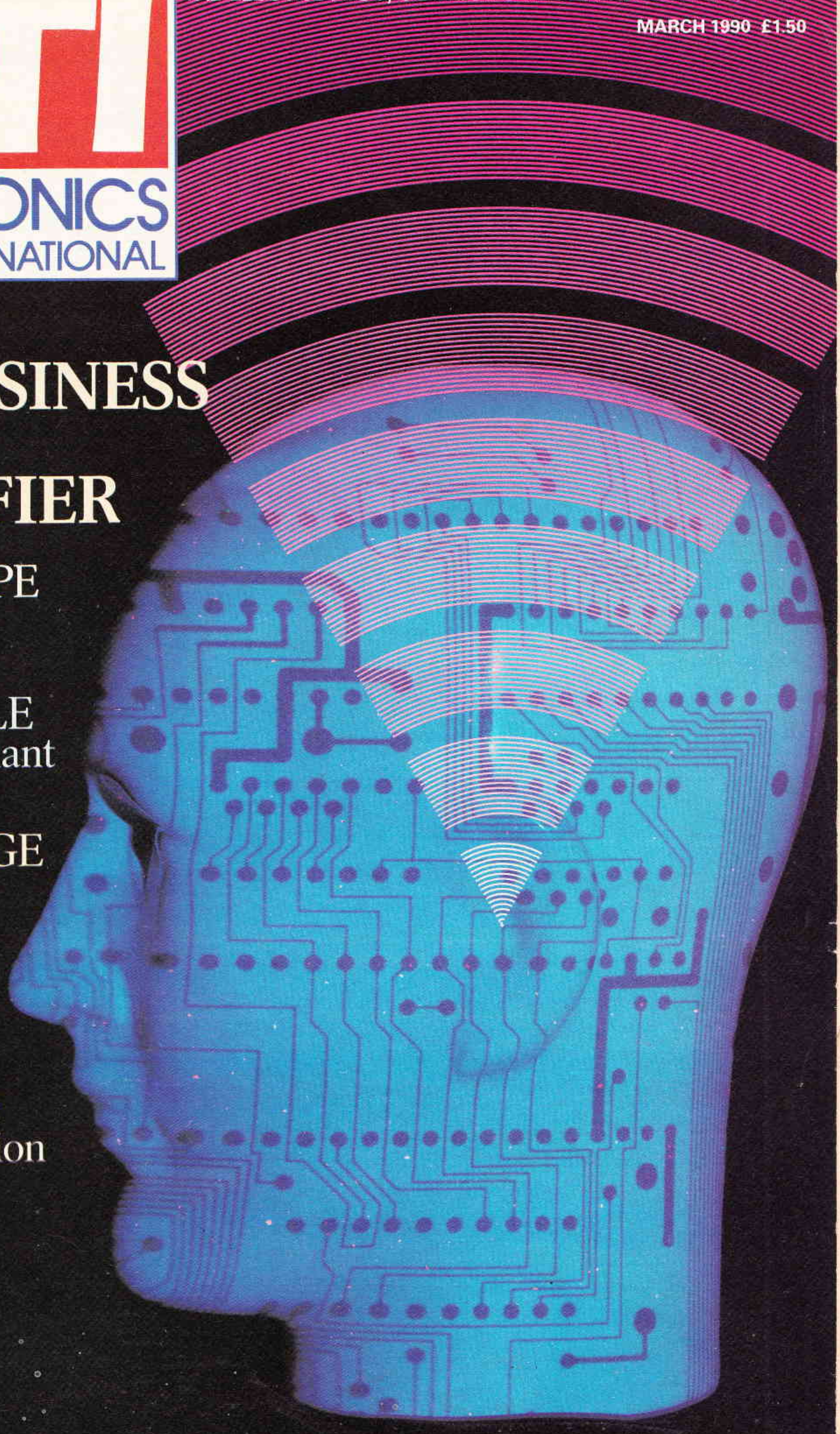
ETI
ELECTRONICS TODAY INTERNATIONAL

THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY

MARCH 1990 £1.50



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BP015B	1	30W dome tweeter. Size 90×66mil *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*
BP027	30	Mixed control knobs
BP028	10	Slide potentiometers (popular values)
BP029	6	Stereo rotary potentiometers
BP030	2	100k wire wound double precision potentiometers *UK made*
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BP039	6	Double phono sockets, Paxolin mounted
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BP042	2	Large VU meters *JAPAN made*
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BP047	1	24V 0.3VA 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)*
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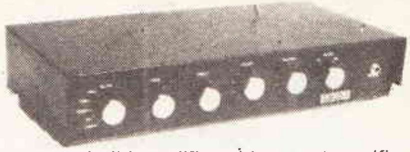
BP055	1	Digital DVM meter I.C. *made by PLESSEY* as used by *THANDAR* with diagram
BP056	4	7 segment 0.3 LED display (R.E.D.)
BP057	8	Bridge rectifiers, 1 amp, 24V
BP058	200	Assorted carbon resistors
BP059	1	Power supply PCB with 30V 4V/A transformer. MC7818CT IC & bridge rectifier: Size 4"×2¾"
BP061	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 chassis socket

30+30 WATT AMPLIFIER KIT



An easy to build amplifier with a good specification. All the components are mounted on the single P.C.B. which is already punched and backprinted.

- 30W×2 (DIN 4 ohm)
- CD/Aux, tape I, tape II, tuner and phono inputs.
- Separate treble and bass
- Headphone jack

Size (H.W.D.) 75×400×195mm

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 preselected 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

£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 HIFI STEREO MAGNETIC CARTRIDGE Fitted with an elliptical diamond stylus supplied with fitting kit and instructions. A good quality unit made to sell 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.)

KOSS MINI SPEAKERS Use instead of headphones on your personal stereo, just plug in instead of headphones. Koss sound cells can be mounted on top of your personal stereo with the holder supplied or simply detach for shelf mounting. This quality unit was made to sell for over seventeen pounds by the KOSS professional headphone company of the U.S.A. Due to a massive scoop purchase we can offer these units for **£4.30** each or buy in multiples of ten and you get one free. Postage £1.50.

KOSS STEREO HEADPHONES High quality light weight stereo headphones fitted 3.5mm jack with adaptor to 6.4mm jack. Ideal use Hifi or personal stereos made to sell for nine pounds. Our price for this unit **£4.25**. Postage 60p.

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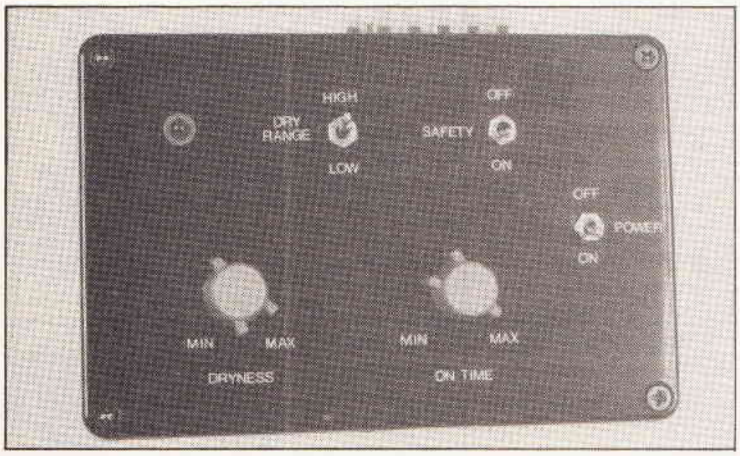

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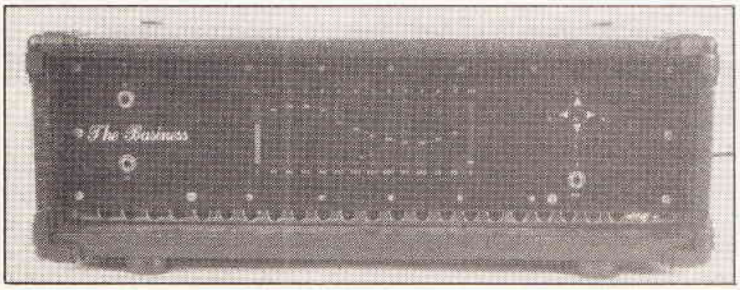

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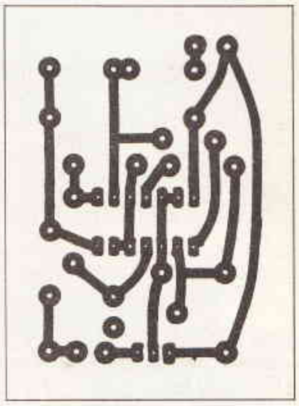

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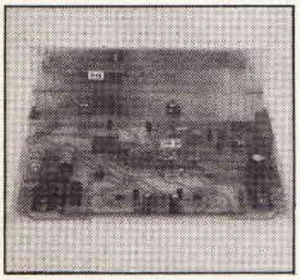
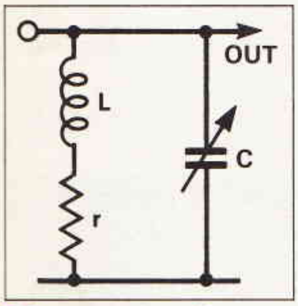
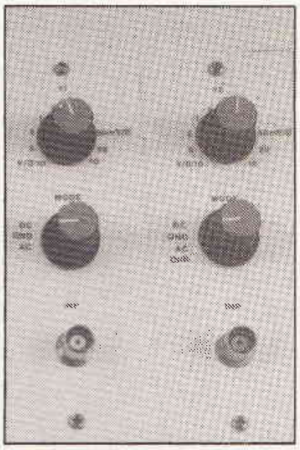
FEATURES/PROJECTS







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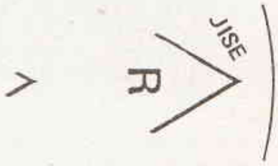

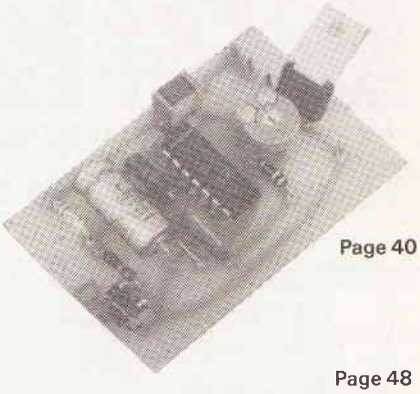

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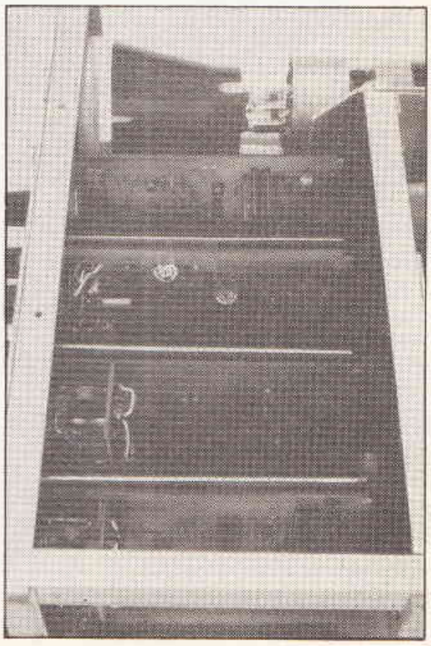


NEWS

BT CSS

British Telecom has proudly announced full operation of its computerised customer service system (CSS) throughout the UK. The system has been built up over the past two years at a rate of two sites per month around the nation, and the last link was Ealing in West London.

Reason for the system was the need for faster processing of telephone enquiries from customers for orders, billing and fault purposes. Previously, anything but the simplest of queries couldn't be processed by BT over the 'phone, but the new CSS system is supposed to ensure even complex enquiries can be dealt with on-line.

CSS is a full integrated screen-based system which gives staff access to a wide range of information, with an average response time of 2 to 3 seconds. In a typical BT telephone district, CSS allows staff to access 1000 on-line programs, 140 million database records, 800 database record types, 50 gigabytes of disc storage, with 2000 screen options.

Apart from the UK system, BT has recently won a contract to supply a similar CSS system to Singapore Telecom, in a deal worth some £13 million.

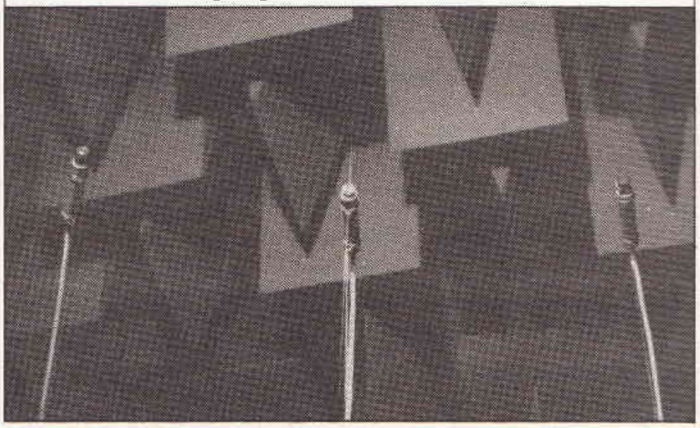
NO REFLECTION ON FORD

Although you might not believe it, the photograph shows a new anechoic chamber built for the Ford Motor Company to test in-car stereo systems. The chamber features an unusual microphone suspension system comprising a series of thin wires (presumably, that's what you can see in the pic holding up the microphone!) which help to minimise sound reflection.

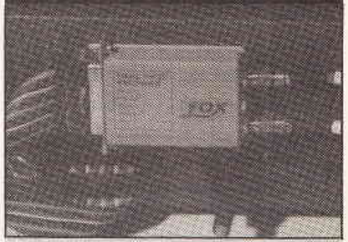
Assessment of loudspeaker performance in an anechoic chamber traditionally relies on microphones arranged at 15° intervals at one metre distance from the speaker under test. Microphones are typically supported on stands or rods, but the actual supports distort the sound by reflection, so producing odd results. The thin wires used in Ford's new chamber are to minimise these reflections, hence giving more accurate results.

The chamber has been built at Ford's research and development facility at Dunton in Essex and is to serve as the European test centre for the entire range of Ford-installed loudspeakers. Ford intends the chamber to be the most advanced such test facility in Europe, and hopes it now has the lead over its competitors.

An extensive range of parameters including resonance, damping factor, one third octave and narrow band frequency response, swept total harmonic distortion, Theil/Small parameters and speaker cone excursion can be measured using the chamber. Any manufacturer hoping to supply Ford will be required to ensure their speakers meet Ford's requirements under such tests.



SIGNALS SEE THE LIGHT



A range of plug-in fibre optic extenders for serial data communications (called FOX) has been introduced by SAS Communications, of Kent. Intended for use with computers, terminals, printers and so on, the devices upgrade the usual serial data distance limitations, to allow communications over distances up to 1km. Protection is also claimed against interference, corruption, electronic surveillance and lightning strikes.

FOX's advantage is that it plugs into the rear of the computer or printer, directly into the usual D-type interface. All standard interface circuits: RS232/V24; RS422/V11/X27; RS423/V10/X26 and so on are accommodated, with a maximum data rate of 100Kb/s. Power can be derived externally, or from the host device, through the D-type connector.

A pair of optical fibres then connects FOX to a similarly placed FOX on the device to be communicated with. Optical fibres of many standard types can be used.

ANOTHER FOOD ALARM

Another example of radio technology in retail outlets has come to our attention this month. Radio Data Systems of London has produced a system specifically to monitor cooling or freezing cabinets in shops and sound an alarm if temperature rises above a predetermined level. The idea is that customers can be assured that chilled or frozen food is being maintained at a sufficently low temperature.

System comprises miniature battery-powered temperature sensors and radio transmitters located in cooling or freezing cabinets, and a central monitoring unit which receives their transmissions. If any transmitter indicates a higher temperature than the preset value, the central unit display will sound an alarm.

Radio Data Systems is quick to point out that the low power requirements of the transmitters, their small size, and the fact that not only temperature sensors may be attached to them make the system ideal for use in many other applications, too, including remote monitoring of industrial processes, or even annunciation systems in burglar alarms.

Radio Data Systems can be found at Merton, London (01 542 1031).

FALLING DISH SALES

News is, that sales of satellite dishes dropped considerably at the end of last year. Surprising really, in the run-up to Christmas! A survey, commissioned by the Financial Times and undertaken by Continental Research, reports that although around 400,000 homes have an installed dish, only 35000 were installed during November. That's against the figures of 72,000 and 122,000 installed during September and October.

Reasons for the decline are thought to be manifold, but the most obvious would appear to be the extensive television and press advertising spent by British Satellite Broadcasting over the months before Christmas. BSB expects to launch its satellite television service in the spring, so it could be we're all waiting for it before we buy.

Whatever the reasons, BSB is experiencing its own problems although these are being played down. First, where are the squarials? Second, where are the chips? Neither have materialized at the time of writing. For further news, watch this space — better still, watch that space (up there, that is!)

HANDY SCANNER

A new hand-held scanning module, with optical character recognition is available from Hakuto. Capable of scanning a document at up to 2 inches per second, the scanner is claimed to have many technical advantages over currently available competitors' products.

For half-tone scanning a selection of six dither patterns are available, coupled with ten brightness and three contrast levels. Resolution up to 300 dots per inch is possible.

Captured image information can be stored in file-types suitable for most desk top publishing software.

Optical character recognition software can recognise 20 fontstyles between 8 and 20 point size, at up to 75 characters per second, although the software may be trained to recognise more.

Captured alphanumeric information can be stored in ASCII, WordPerfect or WordStar text files.

Scanner and software is available from Hakuto International, Waltham Cross (0992 769090).

WALK AND TALK FOR GUERNSEY

The Barclays, Philips and Shell consortium (BYPS) formed to operate one of the Telepoint networks is to supply base stations, network equipment and handsets for the island of Guernsey. The agreement with Guernsey Telecom means that BYPS will be the sole provider of the Telepoint service for Guernsey.

System will be to the common air interface (CAI) standard, which means that handsets from any of the four operators licenced by the Government to provide a service will eventually work in Guernsey. Other operators' equipment, however, does not yet conform to the CAI standard, so BYPS should effectively clean-up on the island.

Guernsey's new system is the first Telepoint service to be built outside the UK mainland.

PHONE SUPPLY FROM DOWN UNDER

From our antipodean correspondent, Trevor Rees, comes a report about a novel use of swtiched mode power supplies.

Australian electrical engineers have invented a 25kg rectifier to replace conventional bulky rectifiers — some weighing 700kg — used in telephone exchanges. Rectifiers transform standard industrial electrcity into 48V DC used for telephone switching gear. Using conventional supplies, an exchange serving 10,000 telephones would need two 200A rectifiers, each 2 metres high and 1.5 metres wide. The Melbourne-based company, Ausmode Power Systems Pty Ltd, has built a prototype 200A rectifier about the size of a shoebox.

Available commercially about now, it will release floor space in exchanges crowded by new generations of telecommunications equipment and allow easier and safer installation and maintenance. Noting that rectifier size and weight were directly proportional to the frequency of the power used in the conversion process, Ausmode's engineers realised that you could increase the frequency and consequently lower the rectifier's size and weight.

The key is to use MOSFETS to increase the frequency of the mains supply and then convert it to 48 volt DC with lighter, smaller and cheaper rectifier materials. Ian Dixon, the electrical engineer who founded Ausmode, believes this switched-mode technology is usable in an estimated 70 per cent of consumer electronics goods worldwide.

He said: "Every piece of electronic equipment coming into Australia has a power supply that converts mains electricity to that used by its own circuitry — these systems are small versions of telephone exchange rectifiers. Ausmode aims at designing and building switch-mode power supply units for export — and also for local installation into imported equipment, where the Government's offset policy encourages some Australian content in overseas manufacturers.

ULTRASONIC TAPE MEASURE

Although ultrasonic distance measurement is almost old-hat now, it's always nice to see a novel implementation of it, particularly when the design and manufacture is British and good looking, too.

Using an offset parabolic horn transducer to transmit and receive the ultrasonic waves, the measure (called *Pulsar* by its friends) features accurate targetting and a consequent large range. Distances of up to some 30 metres can be measured by Pulsar, with an accuracy of $\pm$ 0.5%. This performance is aided by the device's ability to ignore objects partially obstructing the measurement path.

Pulsar also features an integral calculator and memory and, with its RS232 interface, can be linked to computers. All this for just £160, Pulsar is marketed by Fisco Products of Rayleigh.

NEWS ON TWO METERS

We've heard news of a number of meters this month, and details are given here.

First off, is a range of voltage indicators (there are, in fact, two in the range), but we've only one photograph) from TMK Instruments. Both models use two probes to measure AC and DC voltages up to 440V in seven ranges. LEDs are used to indicate voltage — rather than display on a digital or analogue scale — and there is basic input protection to 500V.

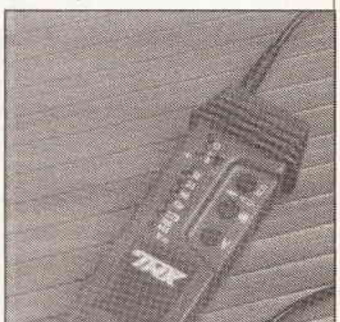
TMK's *ElectroMate* — the one in the photograph — indicates voltage polarity, too, and has a diode and lamp check, along with audible and visual continuity indication. It retails at around £40. The other, *VoltMate*, is a low-cost indicator retailing at around £6.

TMK also has a new digital multimeter, with a combined analogue display. Housed in a yellow case, the *G40* is suitable for all general-purpose multimeter applications including DC voltage to 1000V, AC voltage to 750V, both alternating and direct current to 10A, and resistance to 20M. Other rest modes include audible continuity, diode and h_{FE} tests for transistors. Price is around £75.

TMK Instruments can be found at Wembley, Middlesex (01 908 3377).

Finally, Alpha Electronics is marketing the latest *GoldStar 84* series digital multimeter; model DM-8433. Doubling as a digital thermometer which can measure from −20°C to +150°C, the meter also measures capacitance to 20 microfarad with a 1 picafarad resolution, as well as the conventional voltage, current and resistance ranges expected of DMMs.

The DM-8433 retails at around £75. Alpha Electronics is based in Atherton, Manchester (0942 873434).



OPEN CHANNEL

Pan-European is the in-term in telecommunications these days, so it appears. If you want to look as if you know what you're talking about, just spiel a bit about the telecoms market for all manner of devices such as cellular telephones and pagers; drop a few abbreviations like PCN, CT2, ERMES; and while you're spieling — say *pan-European standard* a few times. If you can find anyone no too bored to listen to all this rubbish, they'll no doubt hail you as an industry messiah (or is it pariah?)

Truth is, the term *pan-European* is a catch-all, generally used when people are trying to get away from the fact that British and other Continental companies are finding it increasingly difficult to compete with foreign (and by foreign, I mean Japanese) imports.

It all seemed to start when cellular telephone systems were in development. Even before they hit the streets, experts were already talking about a pan-European digital standard which would create a new generation of cellular telephones, usable when roaming all over Europe. (Presumably, a customer crossing a border between two countries doesn't need to speak two different languages. Ed.) Now, this is nothing more than an incredibly devious way of moving the goalposts so that the Japanese football misses the goal. In effect, the idea is to sell more European equipment, based on the premise that foreign competition won't be able to keep up with European wranglings.

And if *that's* devious, consider this. Along comes CT2, the second generation of cordless telephone (nothing to do with cellular telephones), known cryptically as *telepoint*. Before handsets are even available to the man in the street (an incredibly deep pun, if you take the time to work it out!), manufacturers and operators alike are talking about a new version of the system. At present, CT2 networks are not compatible — a telephone handset from one operator cannot work on another operator's network. Later this year all networks must conform to a national standard known as common air interface (CAI), which makes all handsets and all networks compatible.

Apart from making existing handsets obsolete, which I'm sure will annoy many customers, this new CAI standard is still not pan-European. Next generation of CT2 handsets will probably be digital, and yes, you've guessed it, totally incompatible with either of the two previous designs.

The same thing is happening in the radio paging field. An international standard: *CCITT radio paging code number 1*, previously known as the *Post Office code standards advisory group* (POCSAG), is no longer any good it seems, to beat off the Japanese, so let's have another one: *European radio message system* (ERMES). That'll do the trick for at least a couple more years. Too bad if the customer is confused and unhappy.

Yes, yes, yes! I know this is somewhat simplistic way of looking at things. But you can't expect the customer to appreciate the intricacies of the arguments for another new generation of equipment standard. The customer doesn't care if one standard only caters for a certain number of users, after which a newer, bigger, better standard has to be created. All the customer is interested in, really, is cost. And new new standard, whether it bears the *pan-European* banner or not, means incompatible equipment; hence artificially raised costs.

A comparison can, and should, be made with the way television broadcasting is about to take a leap forward. The much-used, and much-abused, term *high definition television* (HDTV) generally refers to any television system which displays roughly twice the number of horizontal lines as are displayed by current television receivers. So, European television systems, based on 625 lines should have about 1250 lines to be classed as HDTV.

Initially, Japanese manufacturers suggested a system which has 1125 horizontal lines to be accepted as a world standard. The Americans lapped it up (although even they seem, currently, to be having second thoughts), but here in Europe the various television operators (led by the IBA) decided against it. Remarkably, *their* argument (unlike all the mobile communications operators' arguments for new standards) is that the Japanese HDTV system *is* incompatible with current European television systems.

Consequently, European choice for HDTV is based on a system which will be compatible. Existing television receivers will be able to receive HDTV signals, albeit with a decoder box. Result: happy customer, happy manufacturers, happy operators — *and* a pan-European system which keeps out the foreign competition.

Complaints, That's His Department

Although final figures couldn't be available at the time of writing, it's known that Oftel received somewhere in the region of 32,000 complaints by the end of 1989, about the telephone service provided by British Telecom. This is some 8,000 more than the previous maximum.

Data on Satellite

A recent decision by the Government changes the rules regarding the transmission of digital data via satellite links. Previously, UK satellite data providers could only transmit to UK earth stations, but the change allows transmission to anywhere within Europe, thus opening up the market for the satellite operators.

Mercury Rising

Finally, a note to watch Mercury in the next couple of years. It'll be interesting to see how the company will totally reconfigure its telephone network in the light of its recent Governmental approval to operate a PCN network. Currently, the Mercury network depends on the link to customers over BT local lines.

This is quite restrictive in two ways. First, customers cannot have a simple Mercury connection, they are always connected to the Mercury network by a BT line, so must opt to select the Mercury network (by pressing the infamous blue button). In effect, customers have to have a BT line (and rent it!) even if they don't wish to use the BT network to place their calls.

Second, Mercury must pay a considerable amount of money to BT for this pleasure — some £300 million in the last six months of last year. Not, you'll agree, a pleasant arrangement for Mercury.

With a PCN network, Mercury will have the capability to allow customers to connect directly to the Mercury network — by a radio link! Thus dispensing with the requirements for BT local lines. Whatever the PCN network costs to set up and run, it's bound to be less than the amount Mercury (and, indirectly, the customer) currently pays to BT. Also, it allows the customer to dispense with BT altogether.

All round, this will give even greater savings for the Mercury customer.

Keith Brindley

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.

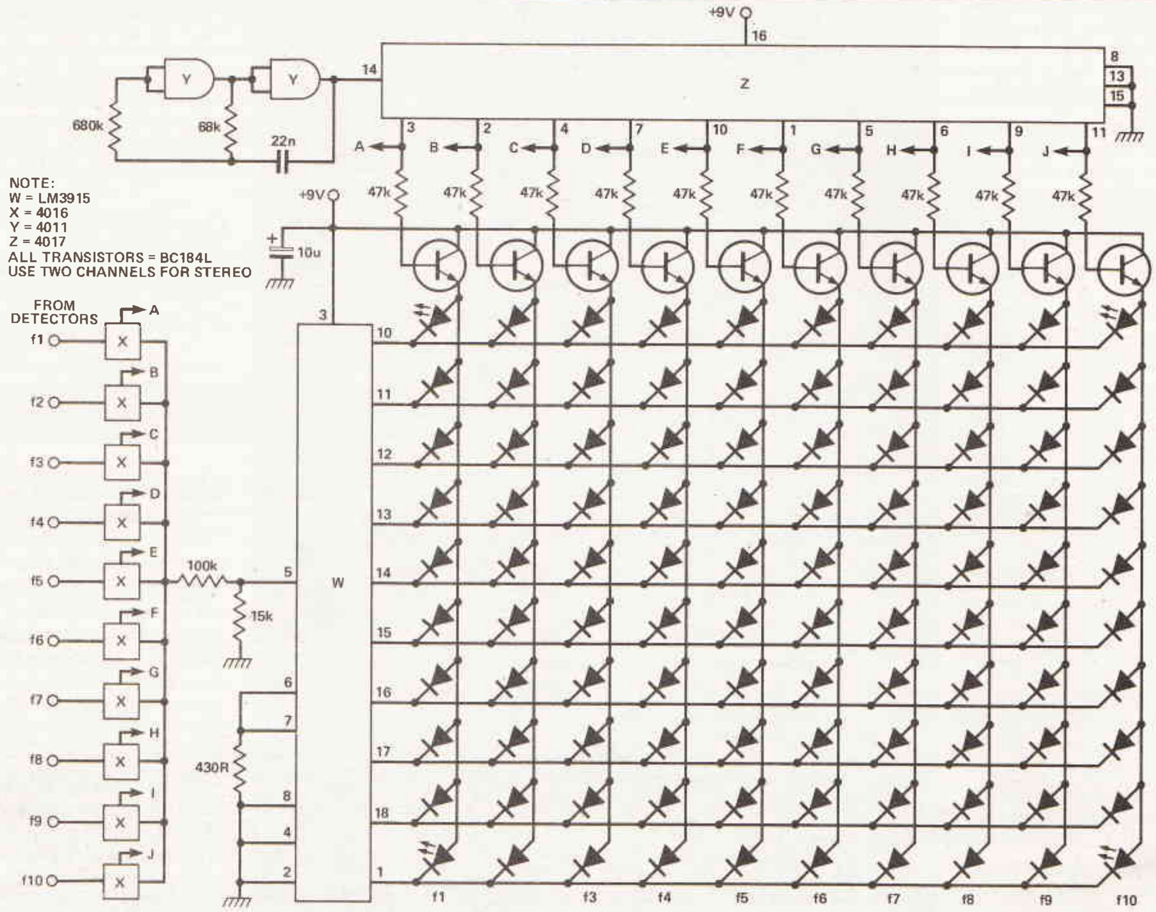


Fig. 1

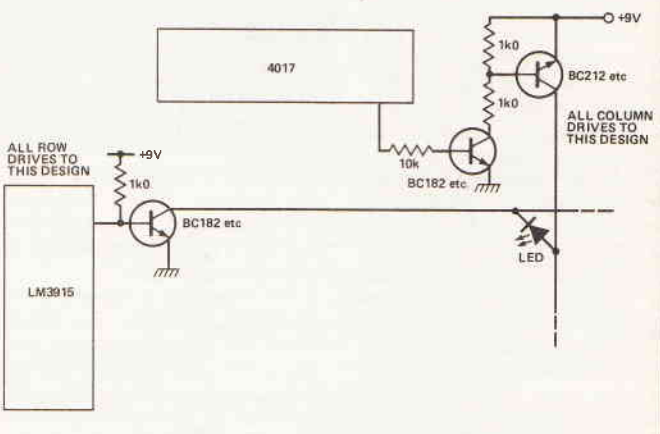


Fig. 2

It's both gratifying and helpful to receive feedback from readers about this column — whether the comments are positive or negative. I have a letter from Malaysia.

Nrin Tan from St Xaviers Institution, who 'went into electronics last year', has some comments and suggestions about the audio spectrum analyser covered in the August 1989 Blueprint. He believes that the design is far too expensive because it uses a separate LM3915 per channel. He has sent a circuit (Fig.1) showing a multiplexed display driving scheme intended to reduce the cost substantially.

He describes how this works: 'The ten outputs from the detectors are fed into the 4016 analogue switches which are controlled by the 4017 decade counter. Only one of the analogue switches is switched on at a time by the 4017 at about 500Hz. The 4017 also switches on one of the transistors, connecting the required column to the +ve supply rail. At the same time the LM3915 (which is set to dot model) turns on one of its outputs, corresponding to the input signal. Clocking the 4017 at 500Hz cycles through all ten columns 50 times per second! So the eye sees ten LEDs continuously lit!

I had considered multiplexing at the time of writing August's Blueprint, but rejected the idea for several reasons. On reconsidering this in the light of Nrin Tan's letter, it might have been useful to have covered this possibility at the time, but there were a few reasons why I didn't.

First was that I think that dot mode does not look right for this application. Multiplexing bar mode, however, needs a substantial driver. Nrin Tan's circuit is barely suitable even to multiplex the unit in dot mode as it stands. The circuit is set for a LED current of approximately 28mA, above the safe limit for long term reliability. A more reasonable current would be 20mA, which would give an average LED current of 2mA. Because the eye responds better to brief than the continuous light, each LED looks brighter than would one LED running at a continuous 2mA.

It's unlikely that the display would be bright enough to be satisfactory when using 0.2in LEDs, although it would look better if small LEDs, which give a more concentrated light, were used. If bar mode were used, then the LM3915 would overheat when used at such a high current per LED. Fig.2 shows a scheme which would be able to multiplex a bar display, or provide a brighter dot display.

Third, another snag when multiplexing LM3915s is that they are sensitive to voltage drops in the earth track, and the variations in voltage drop caused by multiplexing could cause apparent interaction between channels. One way to avoid this problem is to use thick tracks and/or wires for all 0V and power connections, and to route the earth track intelligently so that there is little interaction even if the track has a significant resistance. Attention to this detail can also avoid the ICs oscillating whether or not the display is multiplexed.

Final disadvantage of multiplexing

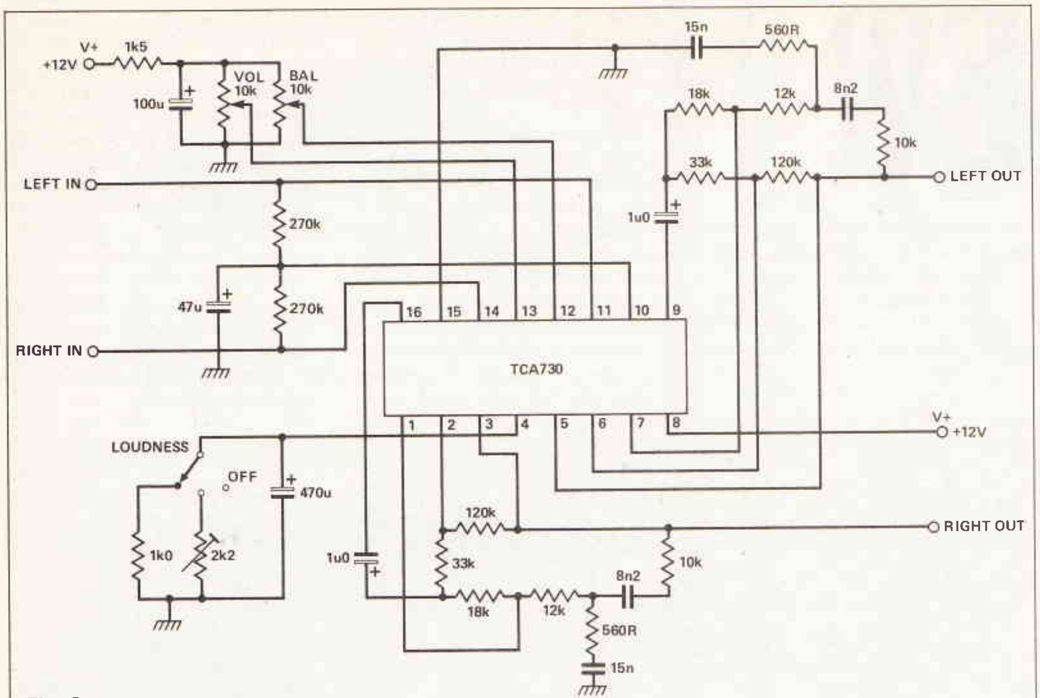


Fig. 3

is that the switching frequency can get into the audio signal, and render the display inaccurate. The answer to this, again, is good layout.

To conclude this subject, some constructors who want the ultimate performance may find that the use of one LM3915 per channel is preferable, while others may prefer the economy of multiplexing.

I have another letter, from D J Bruyns, for whom I recently designed a loudness control circuit. He expresses surprise that a linear potentiometer is shown as the volume control in a loudness circuit, despite the well known need to use a logarithmic pot as a volume control in order to achieve a reasonable control law. The reason for using a linear pot is that the wiper of the 100k pot is connected via a 10k resistor to a virtual earth summing point. This loads the signal on the wiper and distorts the linear law of the pot to give an approximation to a logarithmic control law. To use a log pot in this position would be too much of a good thing.

Mr Bruyns also sent a circuit, gleaned from a catalogue, of an electronic (that is voltage controlled) volume and loudness control, shown in Fig. 3. He asks whether this type of circuit adds distortion to the signal, and if so how much.

In general, all voltage controlled gain circuits introduce distortion, as well as noise, so they cannot be recommended for the best quality hifi. some ICs of this type, however, introduce fairly low levels of noise and distortion, so they can be used on smaller, slightly less critical sound systems. The TCA730 is a Phillips IC intended for use as a voltage controlled stereo volume control. There is a companion IC (TCA740, I believe) which is a voltage controlled tone control. The distortion figures for the TCA730 are as follows:

Distortion at 1V RMS output

Gain dB	Typical distortion	Maximum distortion
+10-+20	0.1%	0.2%
0-+10	0.3%	0.5%
−5-0	0.3%	0.5%
−70-−50	0.5%	1.0%

This performance seems suitable for use in a remote controlled television, or in a small cardboard stereo system, but not in audiophile equipment. I know of one supplier which stocks this IC, along with a wide range of other audio devices:

Dalbani Corporation
2733 Carrier Avenue
Los Angeles
California 90040
Telephone +213 727 0054

REVIEW

If you work frequently with logic circuitry or microprocessors, you'll have come to appreciate the limitations of the simple logic probe. Even a two channel oscilloscope is of limited use in an 8-bit system and it can be difficult to observe events that don't occur very often. The normal solution is a logic analyser — but these are very expensive, well out of the range of the humble hobbyist.

To try to solve this problem, Thandar (maker of the excellent TP1 Logic Probe) has brought out the TA100 Logic Analyser. It has eight channels, each made up of an LED and a switch which can be set to 0, 1, or 'don't care'. If eight bits are not enough for your system, up to four TA100s can be chained together.

The unit operates in two modes; the *trigger* mode freezes the display when the trigger event occurs, while in *free run* mode an output pulse is provided at each trigger event.

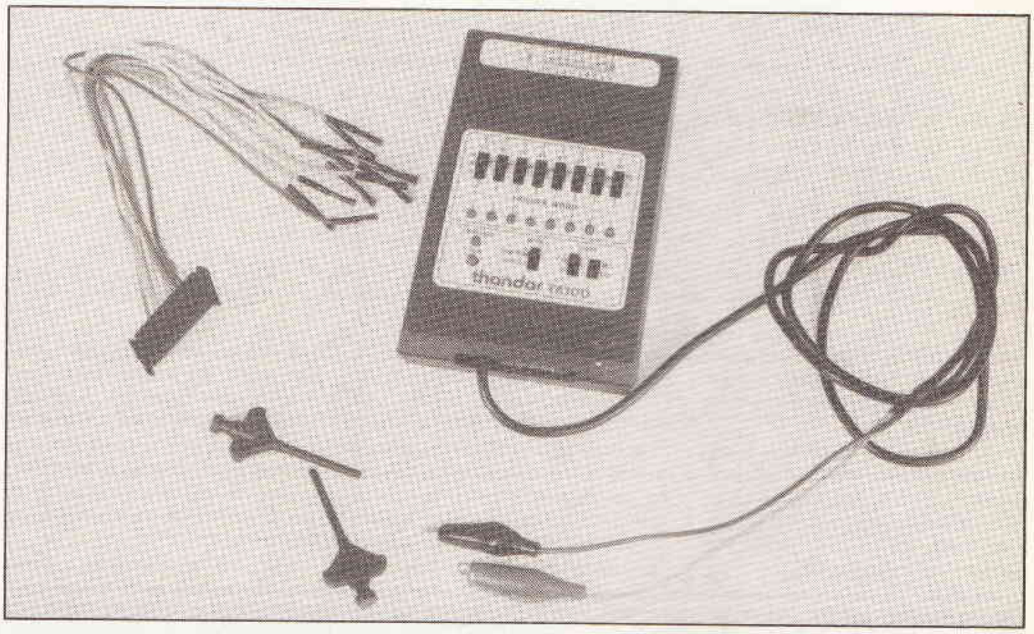
In the first mode, each channel can be set to form part of the trigger word (by setting the switch to a 0 or a 1), or else to display the state of an input when the trigger word occurs (by setting the switch to 'don't care'). There is also an external clock input so that by setting all the switches to 'don't care' and using the external clock, the state of all eight inputs will be shown when the trigger event occurs. Either the positive or negative going edges of the external signal can be selected.

One example of its use in this mode would be to check the data being written to dynamic RAM — the trigger word could be formed from $\overline{RAS}$ (switch set to 0), $\overline{CAS}$ (ditto), and using $\overline{WE}$ as the external clock. The data input to the RAM would be connected to a channel switched to 'don't care', and the data being written to the RAM would be displayed on that channel.

In *free run* mode, the TA100 will provide trigger pulses for another device such as an oscilloscope. In this mode, a 'trigger output' pulse is provided whenever the trigger event occurs. by using a two-channel oscilloscope, displaying the signal under test on one channel and the trigger output on the other, the signal under test can be observed at precisely the time that the trigger event occurs. In addition, by changing the trigger word, observations can be made under different circuit conditions.

A couple of gripes: the literature that comes with the TA100 is not comprehensive; the ± switch for the external clock is not even mentioned. The construction also leaves something to be desired — there is no test point for the trigger output signal, for instance; you have to connect your probe via a piece of wire to one of their probes, to the *trigger output* pin.

In general, though, Thandar has come up with a very flexible and versatile device, well worth considering if you're working with logic circuitry and a simple logic probe is too simple or tedious.



INSIGHT

Birmingham Town Hall is a beautiful building, classical Greek acropolis on the outside, guilded regency within. Packed to the galleries with chattering schoolkids it assumes the atmosphere of a 40s Saturday morning cinema — all ready for newsreels and flying ink blots.

But not today. Today we gather for the 1989/90 IEE Faraday Lecture, 61st in a series that started back in 1924, each presenting a carefully chosen electrically-orientated topic in a form fit for all the family.

This year the topic is 'Electric Currency' — the effects that ever-changing banking systems have upon the way we live and work. One of the underlying motives is to show what fun it can be to be an electrical engineer, and how these engineers make the world a better place.

Presenting this year's lecture is the Bank of Scotland who is, it seems, pioneering the computer banking revolution as well as having a distinguished history, plus the rare privilege of issuing its own banknotes (thanks to some mid-19th century Scottish legislation that prevents the Bank of England telling it to stop).

But on with the show.

Boring Bankclerks

The opening cacophony of sound and vision is abruptly halted by the arrival of our lecturer who bounds to the front of the stage to address us with the enthusiasm of a Blue Peter presenter with a stomachful of happy pills.

"Who thinks that working in a bank is boring then?" she cries.

The air is quickly full of hands — it seems to be pretty much unanimous, sorry bank clerks everywhere but surely a thousand Birmingham schoolchildren can't be wrong.

But apparently we can. Banks can be fun fun fun, particularly if you throw off the mantle of bank clerk and become the more modern 'finance engineer'. Mmm. The audience is not convinced. But then it's only the start of the show.

A Rubber Pig

This year's Faraday lecture is low on the whistles and bangs. Apart from the colourful stage it uses few props — the large film screen, a fake computer, a wheelbarrow and a lifesize foam rubber pig.

Instead it relies on traditional lecturing of the it's-such-fun-isn't-it-boys-and-girls variety. This is interspersed with sketches from the Bank of Scotland's answer to the Dangerous Brothers, who illustrate the history of banking from barter, through gold and banknotes to home computer banking.

All this is filled with some marvellous statistics. For example — the Bank of Scotland's computers guard against power failure using four power supplies from the grid, eight back-up generators and fifty tons of batteries. Another — if all the cheques from a single day at the London clearing house were piled up, the stack would be eight times the height of Big Ben. And retina scans and thumbprint analysis will replace PIN numbers (no mention of quite when, unfortunately).

All this is perfect material to keep the school parties pinned. Occasional forays into film (predictably accompanied by Pink Floyd's *Money* — albeit tastefully edited) prevented lecture fatigue from setting in.

Bank of Scotland (not the Royal Bank of Scotland it was carefully pointed out) got its money's worth of plugging its own specific systems (so Autoteller instead of cash dispensers and so on) and by giving everyone details of its exciting career opportunities, in the lecture literature on the way out.

It would perhaps have been instructional for the question 'how many people think banking is boring' to have been repeated at the close of the show (instructional but perhaps a little dangerous). The overall impression of the slick and stylish show is that banking is indeed become more fun, but primarily for the customer — assuming of course that you keep in credit!

Eleven shows are still to come:

Cardiff St David's Hall	*Jan 16*
Bristol Colston Hall	*Jan 24*
London Barbican	*Jan 30-31*
	Feb 1
Portsmouth Guildhall	*Feb 6*
Leicester De Montfort	*Feb 13*
Sheffield City Hall	*Feb 28*
Dundee Caird Hall	*Mar 7*
Edinburgh Usher Hall	*Mar 13-14*

Tickets are free but in limited supply. For daytime performances contact the venue; for evening shows contact the Faraday Lecture Liaison, Bank of Scotland, Management Services Division, Sighthill Centre, PO Box 403, 2 Bankhead Crossway North, Edinburgh EH11 4EF. Tel: 031-442 7697.

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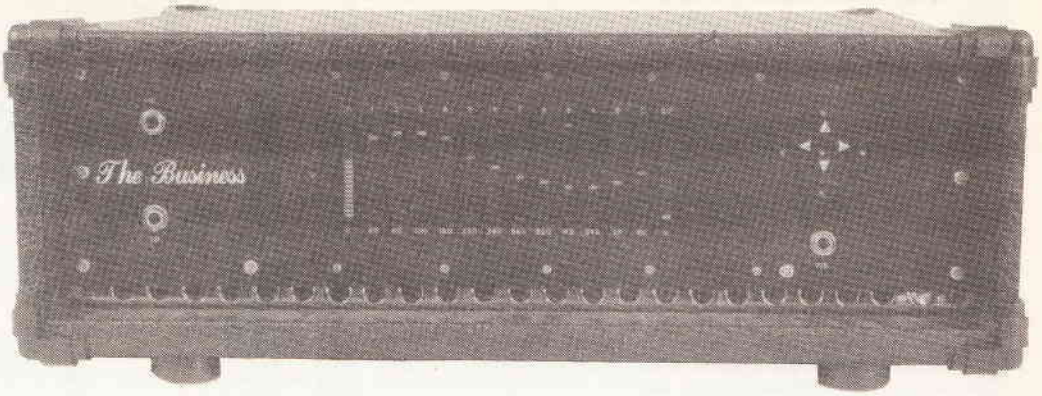


THE BUSINESS AMP

Part 1: The Amplifier Circuitry

Bob Whelan has designed a very sophisticated bass amplifier that can remember all your concert performance levels

PROJECT

What I was trying to get was the sound. I could hear it now and again on records, deep and punchy, and with good definition between the notes, I like the bass guitar to be deep and low, something to feel as well as hear. Reach down and get it boy, play me that low E. Small combos just can't cut it, a compromise between performance and portability. To obtain clean low frequencies and solid deep bass at high sound pressure levels, requires power, and a decent cab, capable of moving a lot of air and pumping out those riffs.

What is needed is an amp with the ability to deliver high power continuously without over-heating, it must also be rugged enough to take the odd knock or two as it is dumped in the van by the roadies gentle hand after a Saturday night bash at the local pallie. Good tone control facilities should be included, and the ability to switch between sound shapes and volumes using a footswitch during the heat of performance would be useful for those tasty little solo bits. That's the way to go. A decent high powered amp top, and the speaker cab can be chosen to suit the job. A compact 4 by 10 for pub gigs, double up speaker cabs by adding a 1 by 15 for a concert rig. Pots and sliders can wear out and become dirty and noisy, but using the LMC835 digital-controlled graphic equaliser chip allows us to get rid of them and use a micro with some heavy duty push switches to control the amp. So that's the design brief, an amp that can operate reliably in a hostile environment, have high tech features, sound good and really do the business.

The Business bass amplifier features:

- 5 push-button control of all amp settings
- 280 LED panel graphic equaliser display
- micro controlled 12-band, 12-channel digital graphic equaliser
- battery-backed ram for recall of 12 different channel equaliser and gain settings
- footswitch or panel selection of 12 pre-set sound shapes
- digital pre-gain and post-gain control for optimum signal levels
- fan cooled bullet proof power amp
- 200 watts into 8 ohms or 320 watts into 4 ohms
- anti-thump turn on/off circuit
- dc offset loud speaker protection circuit
- micro watchdog circuit.

Figure 1 is a block diagram of the signal path through the amplifier. The amplifier has two imputs, high gain input for passive guitars and a low gain input for active guitars. A normally open switch on the HI input jack socket automatically selects the gain. The next stage in the amp is a first order high pass filter with a turn-over point of 30Hz and a 6dB/octave roll off to reduce sub-audio noise and clean up the deep bottom end. The gain and volume control circuits use the AD7110 C-MOS digitally controlled audio attenuator IC. The Business bass amplifier features a digital graphic equaliser that has +/− 12dB of cut or boost over 12 frequency bands that has been chosen to give good tonal control over the bass guitar range. Centre frequencies of the equaliser are: 40Hz, 60Hz, 100Hz, 160Hz, 250Hz, 380Hz, 660Hz, 820Hz, 1K3Hz, 2K6Hz, 5KHz, 8KHz. The amplifier

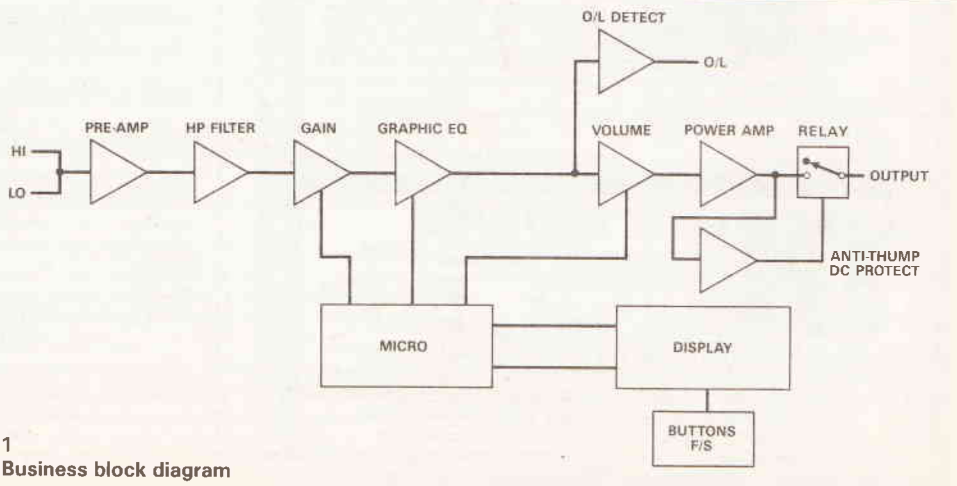


Fig. 1
The Business block diagram

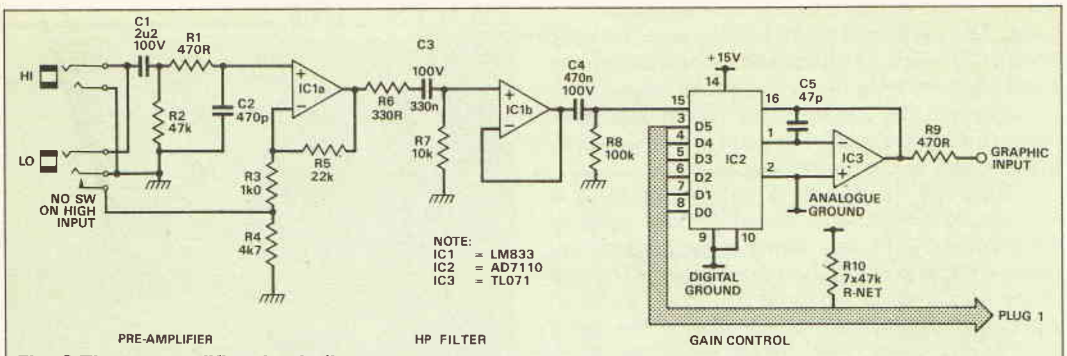


Fig. 2 The pre-amplifier circuit diagram

has a 6502 based micro circuit to control the various functions. 12 channels of equaliser and gain settings are stored in battery backed memory. This allows instant sound changes during performance using a footswitch to change channels. The front panel display is made up from 28 10-segment bar graph LED modules arranged as 14 columns of 20 LEDs. Column 1 is a gain display in green LEDs, the next 12 columns are graphic equaliser band settings in red LEDs and the 14th column is the volume display, again in green LEDs. The lower 19 LEDs of each column indicate level settings, and the top LED in each column indicates status. The top LED on the gain column indicates overload, the top LED in the graphic columns is active channel, and the one in the volume column is set/play mode. The display is driven by a M5450 led driver IC. The power amplifier is a no frills basic design incorporating high-voltage transistors in the voltage amplifier stage and eight power MOSFETs mounted on a forced air-cooled heatsink in the output stage. Output short circuit protection is provided. Measured output power is 200watts into an 8R load and 320wattsinto a 4R load. The amplifier exhibits no ringing when driven at 10KHz into 8R in parallel with 2μF. The output is connected to the speakers via a 16amp single-pole change-over relay. The anti-thump circuit delays relay closure for 2 seconds at turn-on and opens the relay almost instantly at turn-off. Speaker DC protection is provided by a window comparator, threshold being set at 2 volts DC offset.

Amplifier operation

Each time the amplifier is turned on, it selects graphic channel one and recalls the last volume setting but mutes the volume. Stepping the volume up or down unmutes the amp ready for playing. The amplifier has 5 buttons for control. These are arranged in a centre, north, south, east and west configuration. The amp has two modes of operation, play and set. The amplifier mode is indicated by the topmost LED in the volume column of the display. Pressing the centre button toggles the mode between set (LED on) and play (LED off). When the amp is in the play mode, the north button increases the volume, the south buttons together zeros the volume for panic feedback situations. Pressing the east button or right footswitch changes the channel up, pressing the west button or left footswitch changes the channel down. The topmost LED in the graphic display columns indicating the active channel. To adjust the graphic settings for a channel, the centre button is pressed to enter the set mode, the east button now steps the band up, the west button steps the bands down. The topmost LED

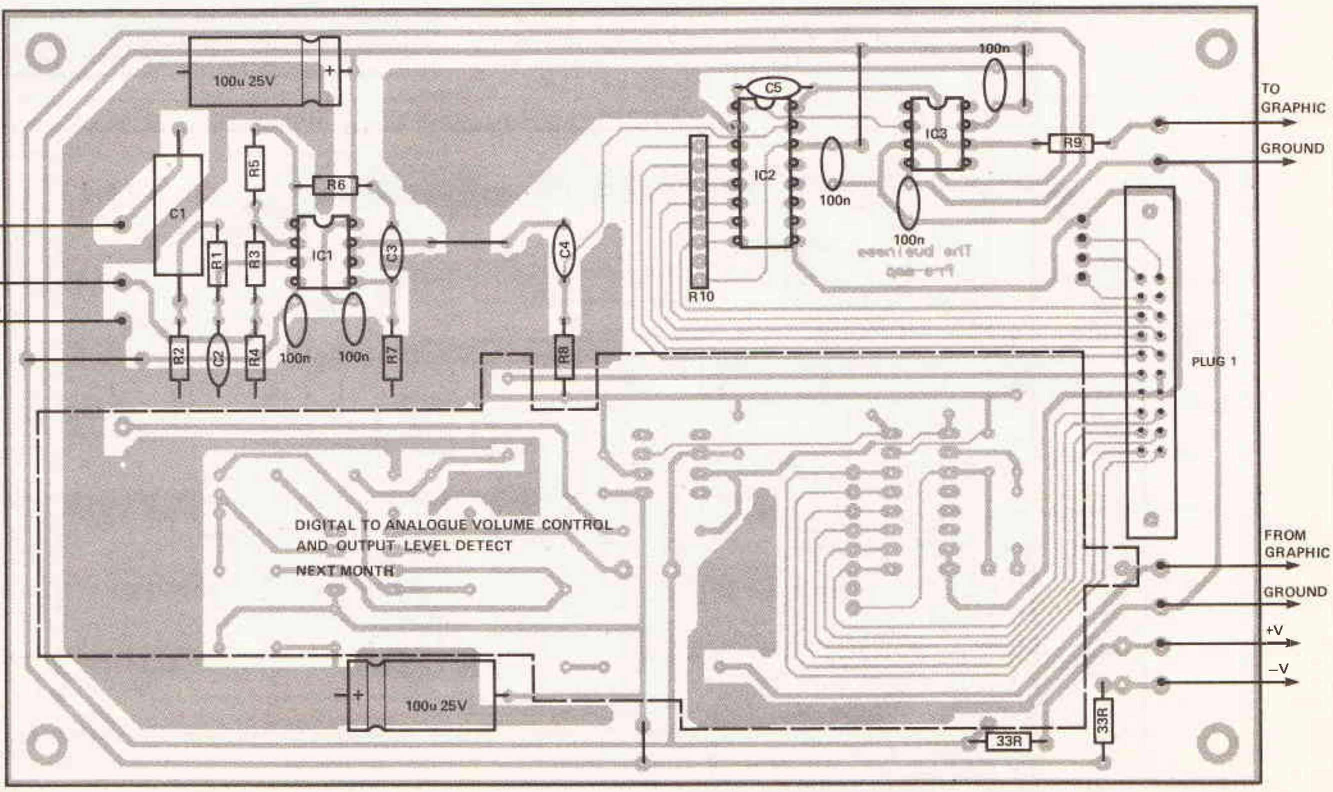


Fig. 3 Component overlay for the pre-amplifier

in the graphic display columns indicating the active band. The north and south buttons step the band boost or cut levels. The gain level for the channels can also be set. Pressing the centre button changes the mode back to play and stores the channel settings in memory for instant recall. The amp is very easy to use, in fact easier to use than it is to describe.

Although the system is quite complex, it is modular in design and therefore quite easy to construct and get going. Some of the modules are useful enough to be used in other projects. The cost of the amplifier will be about half the price of an equivalent commercial model offering the same facilities and power. This cost can be spread over a period as and when the parts are required for each section.

Assembly of the Pre-amp

The pre-amp board is mounted in a diecast aluminium alloy box (Maplin box DCM5006), which serves the double purpose of screening and support. The board is fixed in the die cast box using M3 × 30 screws and M3 spacers. Two M4 holes should be drilled in the side and near the top of the box for mounting onto the main amplifier chassis. A hole should be drilled at each end and near the lid of the box for the power supply leads and signal leads. Rubber grommets should be put in these holes. To prevent stressing the solder joints, the 20-pin plug on the pre-amp board should be screwed to the board. Assemble the pre-amp PCB according to the overlay diagrams. Suggested order of assembly being terminal pins, links, IC sockets, resistors, capacitors, semiconductors and finally plug in the ICs. The 7110 attenuator chip is a C-MOS type and requires careful handling. The pre-amp board can be tested by powering it up with +15, −15 and earth and injecting a 1KHz sine wave into the input while monitoring the output with a scope. A change in gain can be seen by taking the 7110 control lines to earth with a short length of wire. The overload detection circuit should be set up by injecting a 1KHz 10 volt RMS sinewave into the input and adjusting the pre-set until the output from the circuit goes low.

Single core screened cable flying leads for the pre-amp input, output and gain switching should be

PARTS LIST

PRE-AMP	
RESISTORS (all ¼W 5%)	
R1,9,12	470R
R2	47K
R3	1K
R4	4K7
R5	22k
R6	330R
R7	10k
R8	100k
R10	7×48k
R11	100k
R13	7×48k
R14	470k
R15	220k
R16,17	15k
R18	510R
RV1	20K Muti turn cermet
2 off	33ohms
CAPACITORS	
C1	2.2µ 100V polyester
C2	470µ polyester
C3	330n 100V polyester
C4,8	470n 100V polyester
C5,7	47p polystyrene
5 off	100n ceramic decoupling capacitors
2 off	100µ 25V electrolytic
SEMI-CONDUCTORS	
IC1	LM833
IC2,4	AD7110
IC3,5	TL071
IC6	TL072
D1,2	IN4148
MISCELLANEOUS	
1	IDC 20-way plug with locking ears 10 terminal pins
4 off	8-pin IC sockets
2 off	16-pin IC sockets

BUYLINES

All the components are easily available. The AD7110 audio attenuator is available from Eletromail part no. 303-747.

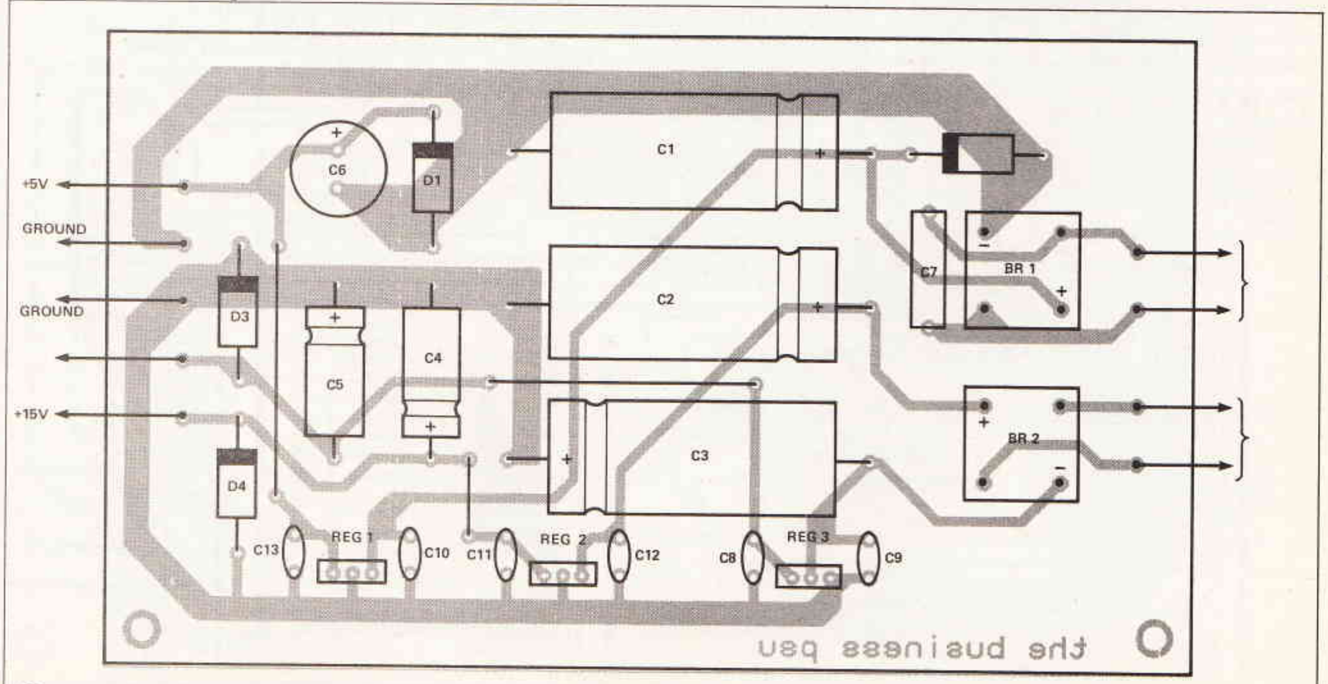


Fig. 5 Component overlay for the pre-amp power supply

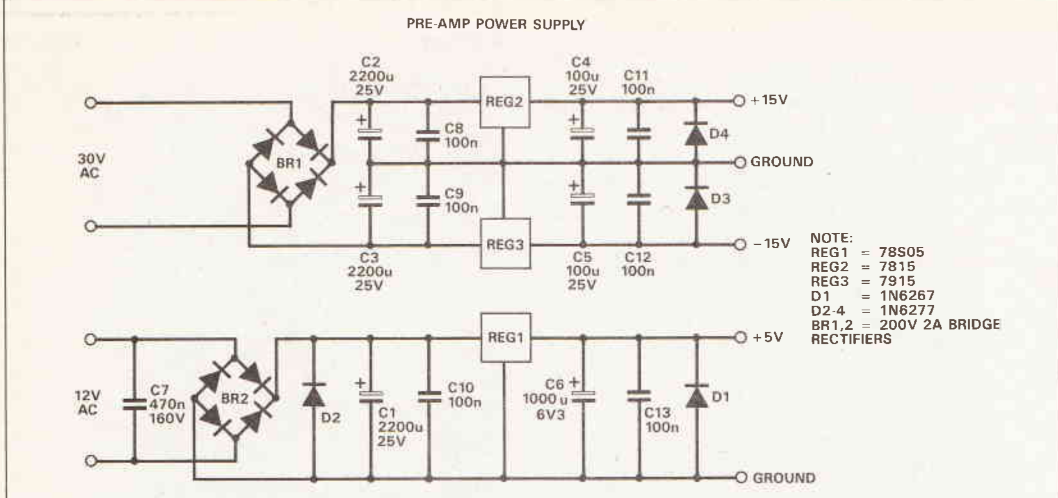


Fig. 4 Pre-amp power supply

passed through the rubber grommet in the left end of the diecast box. The power supply and earth leads should be passed through the rubber grommet into the right-hand end. Use 16/0.2 wire for the power leads and 32/0.2 wire for the earth leads.

Pre-amp Power Supply

A 6.5 inch length of 1.5 inch aluminium angle acts as a mounting bracket and heatsink for the pre-amp power supply. Use the PCB as a drilling template to mark and drill out the two M3 board mounting holes and the three M2.5 IC regulator mounting holes. Solder in all the components except the regulators using the PCB overlay diagram (Fig. 5). The board can now be bolted to the aluminium mounting bracket using M3 screws, flat washers and full nuts. The IC regulators can now be inserted into the PCB and be bolted on to the bracket. Only REG 3, the 7915 requires a mica or silicon insulating washer. Once the regulators have been bolted-down, they can be soldered on to the PCB. REG 3 should be checked for isolation from the bracket. The board is pretty straightforward and can be tested once it is mounted in the chassis and connected up.

General construction

Serviceability is an important consideration and so high quality sockets should be used for all the ICs in the amplifier. Turned pin types are to be preferred for the best realibility. Some of the chips are CMOS types and require careful handling. Do not remove them from their packing until they are needed. An earthed wrist strap is the best method of working with these devices. All wiring connections to the PCBs should be made to terminal pins as opposed to soldering the wires to the boards. Solder is not a glue, it is used to made an electrical connection, so simple lay-on joints are not acceptable. The wire should be stripped back, tinned with solder, bent to fit around the terminal pin and trimmed. Once a secure mechanicl connection has been made, the solder can be applied to complete the electrical connection. Only use plated or stainless steel fixing screws, washers and nuts to prevent rusting. All the PCBs should be defluxed and cleaned after assembly using a proprietary cleaner. Once the boards have been tested and are working, they should be sprayed with PCB varnish on the foil side. Care and attention to detail during construction will be more than repaid with a reliable and long lasting amplifier.

Power Amplifier Construction

A 6.5 inch length of 1.5 inch aluminium angle acts as a mounting bracket and heatsink for the power amplifier. The 25watts 0R15 series output resistor is positioned on the aluminium bracket and fixed using M2.5 countersunk screws (see photo). Use the PCB as a drilling template to mark and drill out the two M3 board mounting holes and the two M2.5 driver transistor mounting holes. Solder in all the components except the driver transistors Q6 and Q7 using the PCB overlay diagram (Fig. 6). The 0R33 2.5w source resistors should be mounted with about a

PARTS LIST

PRE-AMP PSU

CAPACITORS	
C1,2,3	2200µ electrolytic
C4,5	100µ 25V electrolytic
C6	1000µ 6V3 electrolytic
C7	4n7 160V polycarbonate
C8,9,10,11,12,13	100n ceramic
SEMICONDUCTORS	
REG1	78S05 2A 5V
REG2	7815 1A 15V
REG3	7915 1A −15V
BR1,2	2A 200V Bridge
D1	1N6267 6V8 high speed suppressor diode
D2,3,4	1N6277 18V high speed suppressor diode

BUYLINES

All the components are readily available. The suppressor diodes are available from Electromail part no. 283-255 for the 6V8 diode and 283-277 for the 18V.

HOW IT WORKS

PRE-AMP PSU

The pre-amp and micro power supplies are simple rectified smoothed and regulated using the 78 series of regulators. The micro supply uses the 78S05 which is a 2 amp regulator. As the amp will be operated in places that are likely to have noisey mains supplies due to disco lighting and various other types of high current switching, some form of voltage transient suppression is required. These transients can feed through the regulator and cause the micro to crash and possibly be damaged. If the regulator load shorts out, the regulator can be destroyed by subsequent transients. D1 to D4 are PN silicon transient voltage suppressors that have high surge handling capability and very fast response time, they are specifically designed for transient suppression. Their reverse standoff voltage is selected to just exceed the maximum continuous voltage. Any voltage spikes exceeding this level are clamped out.

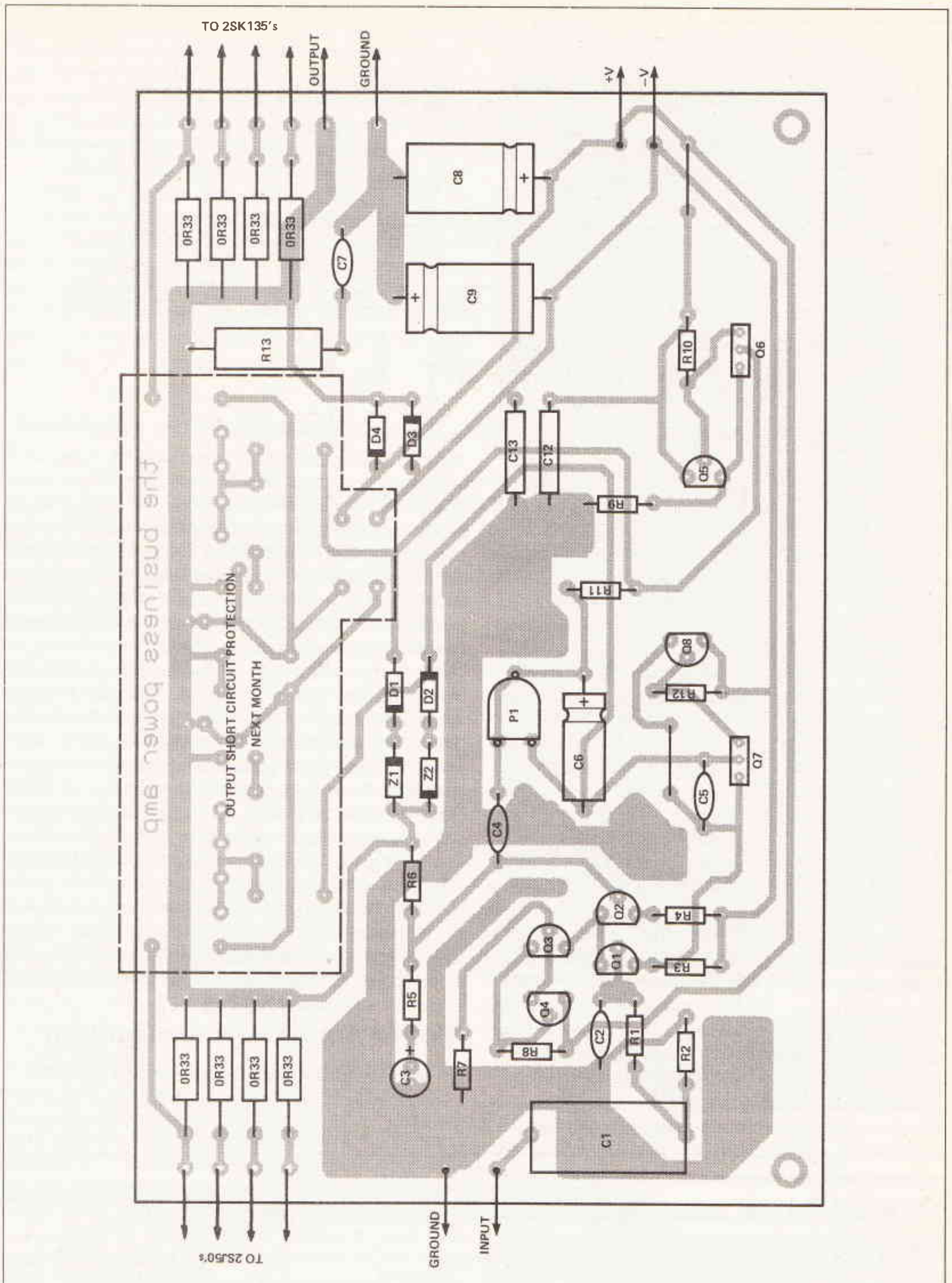


Fig. 6 Component overlay for the Power amplifier

HOW IT WORKS

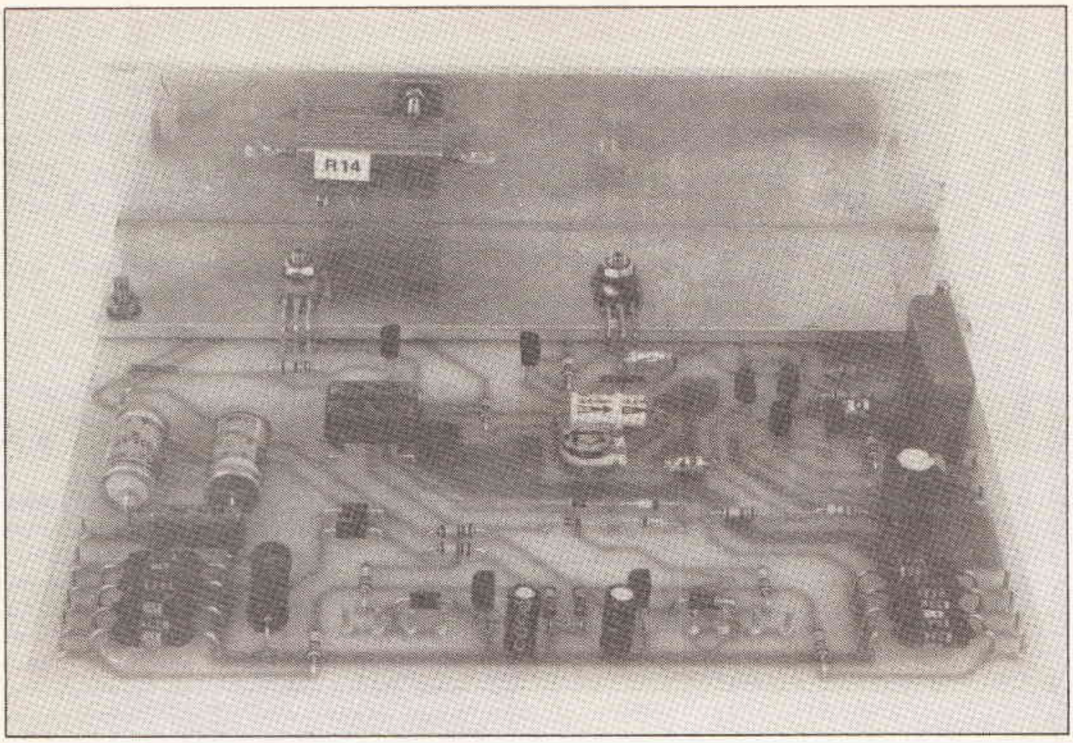
PRE-AMP

The amplifier has two imputs, a high gain input for passive guitars and a low gain input for active guitars. A normally open switch on the HI input jack socket selects the gain. Gain of the input stage is set by (R5+R3)/R3 for the high input and by (R5+R3+R4)/(R3+R4) for the low input. The gain of the input is 4.8 when the LO input jack is used, and 23 when the HI input jack is used. These sensitivities are suitable for active guitars with outputs of 500mV-1V and passive guitars with outputs of 50-100mV. Gains can be easily adjusted for special cased by changing the ratio of feedback resistors.

The input stage is an LM833 op-amp configured as a non-inverting amplifier. The LM833 is a high performance dual op-amp with low input noise (4.5nV/√ξ(Hz) typical), large gain bandwidth product (15MHz), high slew rate (7V/μs), low THD (0.002% 20Hz-20KHz), and unity gain stability. The LM833 is used extensively in the amp.

The next stage in the pre-ampo is a first order high pass filter with a turn-over point of 30Hz and a (dB/octave roll off to reduce sub-audio noise and clean up the deep bottom end. Turnover frequency is set by C3 and R7.

The gain and volume control circuits use the AD7110 C-MOS digitally controlled audio attenuator IC. The addition of one external op-amp enables an audio signal to be attenuated in 1.5dB steps via a 6 pit input code. The circuit features low distortion, the THD being better than −98dB. IMD better than −92dB and good S/N ratio :100dB(20Hz-20KHz). The IC has a digital ground pin and an analogue ground pin to reduce breakthrough of the digital control clock pulses to the audio signal. The front panel display allows for 19 steps and these have been chosen by trial and error to cover a useful range of levels. The steps chosen are: 60, 34, 31, 29, 26, 23, 20, 17, 15, 13, 11, 9, 7, 5, 4, 2, 1, 0. Each step represents 1.5dB of attenuation.



Power amplifier main board showing R14 mounted on the heat sink

quarter inch clearance from the board to aid in cooling. The board can now be bolted to the aluminium mounting bracket using M3 screws, flat washers and full nuts. The driver transistors Q6 and Q7 can now be inserted into the PCB and be bolted on to the bracket. They both require a mica or silicon insultaing washer. Once the transistors have been bolted-down, they can be soldered on to the PCB. They should be checked for isolation from the bracket. The board should be carefully visually checked as it will only be tested once before it is wired-up and ready to go in the chassis.

HOW IT WORKS

POWER AMPLIFIER

The input to the amp is a band pass filter type. C1 and R2 limitng the low frequency response and R1 and C2 limiting the high frequency response. R1 + R2 is also close to the value of the feedback resistor R6 for impedance balance in the input pair.

Current through the input pair Q1 and Q2 is set at approximately 1mA by the constant current source made up of Q3 and Q4, R9 setting the current at 0.6V (Q4's turn on voltage) divided by R9. The differential input pair forces the output of the amplifier to follow the input signal times the gain factor. A positive signal at the base of Q1 reduces the current through its collector, causing the potential across R3 to fall, resulting in the voltage amplifier transistor Q7 turning off. This causes the potential to rise at Q7's collector, turning on the positive N type output MOSFETs and forcing the output of the amplifier to rise positively. This is fed back through resistor R6 to the base of Q2, the amplitude of the feedback signal being attenuated by the ratio of R6 to R5, thus setting the gain. Q2 is turned off, forcing Q1 to sink more of the 1mA constant current which Q1 and Q2 share. This increases the potential across R3, turning on Q7 and reducing the voltage on its collector, turning off the output stage, until a balance is achieved. The output settling at the input potential times the gain.

The constant current source made up of Q5 and Q6 provides approximately 10mA for the voltage amplifier Q7, R10 setting the current at 0.6V/R10. Q7 also provides adequate drive, smoothed by C6, for the output stage MOSFET devices. The static input impedance of MOSFETS is very high as the insulated gate is practically an open circuit. Dynamically, the gate impedance reduces with increasing frequency. This is due to the input impedance appearing to be a capacitor between the gate source and gate drain junctions inside the device. In high frequency switching applications, these capacitors are fully charged and discharged at each cycle and so some power, albeit very small, is required for adequate drive to the MOSFET gate. In the amplifier, the output stage is biased into class AB and so never completely turns off. By this means, the gate capacitors are charged up to a working level and are never fully discharged and recharged by the audio frequency response or the slew rate of the amplifier, which is comparatively slow to the MOSFET. Q8 limits the current through Q7 during fault conditions. C4, R11, C6 and C5 provide frequency compensation for the front end of the amplifier. Voltage gain of the amplifier is set by (R5+R6)/R5 at 28.

The output stage uses 8 Hitachi power MOSFETs, 2SJ50 p types and 2SK135 n types in a complementary output configuration for good bass response. These devices are rated at 100w power dissipation, drain currents of 7A. As MOSFETs are bulk carrier devices that do not suffer from secondary breakdown, much higher peak currents can flow through the devices without damage, temperature being the limiting factor. They are more rugged that bipolar transistors when used as amplifier output devices due to their well known self limiting characteristics of increasing on resistance with rising temperature. MOSFETs also exhibit a reducing gate source threshold voltage with rising temperature coefficient, whereby a simple output stage biasing arrangement will maintain a constant bias current through the output stage without the need for any form of thermal tracking arrangement. Pre-set resistor RV1 sets the output bias current. This is adjusted for 120mA through each device. The zenner diodes Z1, Z2 protect the MOSFET gates against excessive voltage drive during overload conditions which could lead to breakdown of the devices internal gate oxide coating. The high frequency response of the MOSFETS combined with comparatively long leads to the pins could lead to some instability in the output stage. The 820R resistors mounted on the gate pins of the MOSFETs help to dampen out and prevent these spurious oscillations in the output.

Short circuit protection is provided for the output stage as the MOSFET devices can be destroyed if they are allowed to get too hot. This is conventional V/I type limiting. Taking the positive side as an example, R15 and R16 monitor the voltage across the output device and R19 and the source resistor monitor the current through the device. If too much current is being passed with too much voltage across the output device, Q9 is turned on stealing gate drive voltage and limiting the power output.

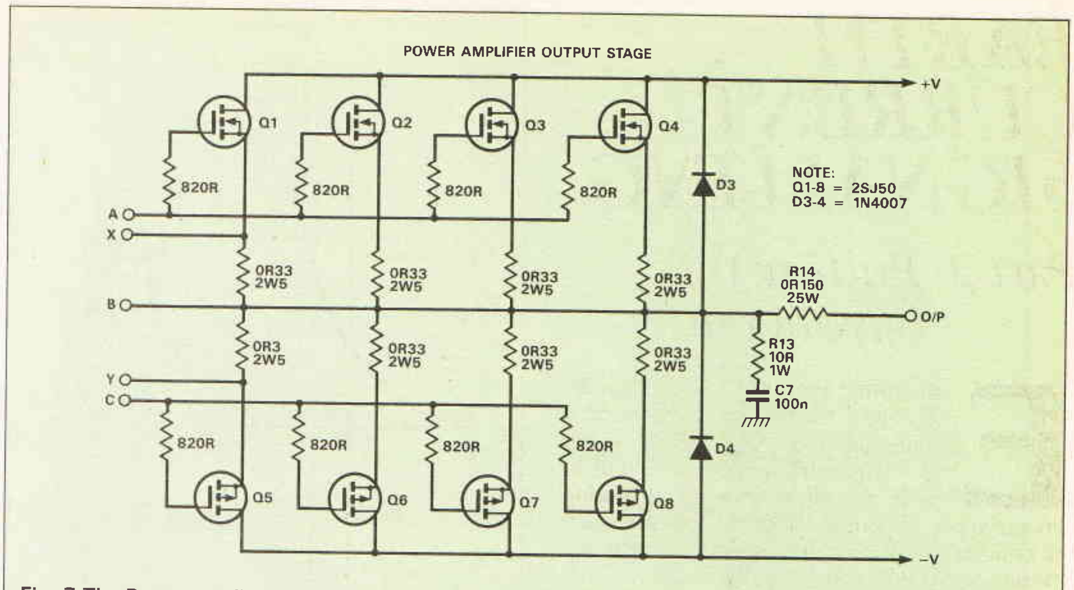


Fig. 7 The Power amplifier output stages

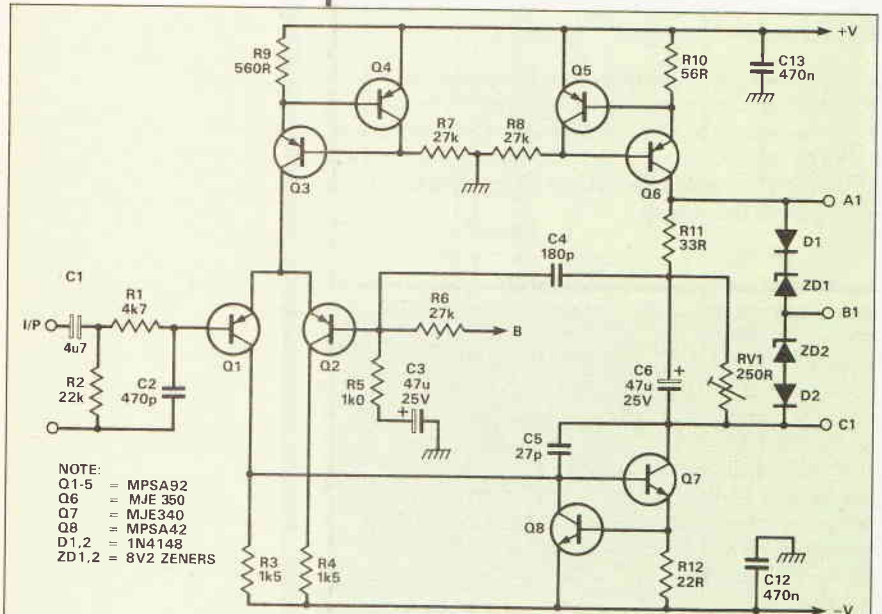


Fig. 8 Main circuit of Power Amplifier

Note that C1 in Fig. 8 is a 4μ7 non polarised capacitance and a suitably sized component should be bought to fit the PCB.

In part 2 we continue the circuit description, including the digital to analogue volume control, output level detect and the micro board for overall control. The DAC volume and output level detect is constructed on the pre-amplifier board inside the box shown in Fig. 3.

The output short circuit protection will be described and constructed. This fits between the power amp and power amplifier output stages and is constructed on the power amplifier board (see Fig. 6).

It should be emphasised, if the reader is interested in constructing the Business Amp, that you should wait for the rest of the article to appear in the following issues of ETI to get an overall perspective of the modular system. Meanwhile you might care to find what surplus components you have to hand.

PARTS LIST

POWER AMP

RESISTORS (all ¼W 5%)	
R1	4K7
R2	22K
R3,4	1K5
R5	1K
R6-8	27K
R9	560R
R10	56R
R11	33R
R12	22R
R13	10R 1w
R14	0R15 25w
8 off	820R gate resistors
8 off	0R33 2W5 emitter resistors
RV1	250R cermet pre-set
CAPACITORS	
C1	10μ polycarbonate
C2	470p polystyrene
C3,6	47μ 25V radial electrolytic
C4	180p polystyrene
C5	27p polystyrene
C7	100n polyester
C8,9	47μ 100V electrolytic
C12,13	470n 100V polyester
SEMICONDUCTORS	
Q1-5	MPSA92
Q6	MJE350
Q7	MJE340
Q8	MPSA42
4 off	2SK135
4 off	2SJ50
MISCELLANEOUS	
D1,2	1N4148
D3-6	1N4007
Z1,2	8V2 500mW zenner

EARTH CURRENT SIGNALLING

Part 2: Putting the bayonet in

George Pickworth continues his fascinating series on ground communication

Earth current signalling has traditionally been with audio frequencies, but usable frequencies may well extend much higher. Generally with frequencies up to 10kHz, the effect on a signal passing between a pair of normal 100-200m bases is much the same as that of a resistive attenuation network: a strong signal is injected into the soil and weak identical signal extracted. Bases can therefore handle sine waves pulse waveforms and complext speech waveforms up to the high audio frequencies. Communication can be by sine wave (tones), audio frequencies (direct speech), pulse waveforms (power buzzer) or even sytonized systems, where the transmitter and receiver are tuned to a specific frequency. In this latter case, signalling can be by keying or modulation.

Earth current communication does not fall within Wireless Telegraphy Acts so there are virtually no restrictions on experiments, provided that they do not cause interference to other services or generate electromagnetic waves.

Selecting a Site

Range is directly proportional to base length, indeed, given a long enough base and unlimited power, infinite range is theoretically possible! Bases at least 100m long are desirable, although not essential, for worthwhile experiments but unfortunately, in urban areas, lack of space and pollution by currents leaking from power lines, can seriously restrict earth current experiments. The author is fortunate in having access to farmland and sees no reason why other experimenters should not make similar arrangements.

When approaching a farmer for permission to conduct experiments on his land, it must be appreciated that the farmer will naurally fear that gates will be left open allowing livestock to escape or that crops may be damaged. There will also be the fear that wire will be left lying about and get entangled in machinery or that earth pins may be left in the soil and wreck combine harvesters. It is therefore vital to convince farmers that these fears are unfounded. Electronics play a vital role in modern agriculture and many farmers have good knowledge of electricity and electronics, so it is important to explain fully the purpose of the exercise and that bases will be laid along hedgerows creating minimal intrusion. Having said that, experimenters should not be surprised if a farmer shows considerable interest in the project and is willing to co-operate.

Landowners diversifying their activities towards caravan sites and recreation may grant permission for a small fee. Indeed, serious experimental work may well be combined with a pleasant break in the countryside. Roadsides and lay-bys in rural areas may seem attractive sites, but experimenters are reminded that it not only contravenes the law to lay bases alongside a road in any place open to the public, but may well create serious problems with regard to public liability.

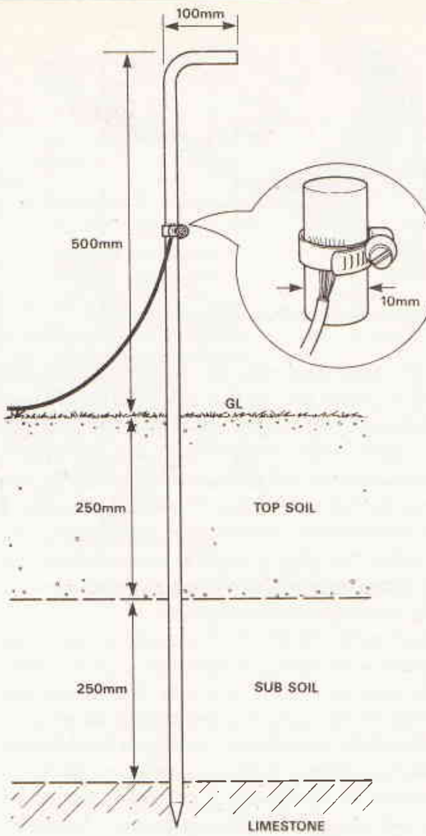


Fig. 1
Steel Earth Pin and profile of soil on author's site

The author works alone, and because the transmitter operates automatically and unattended, commuting between the transmitter and receiver sites was an important consideration in selecting a site. Moreover, a range was required that could be used over a long period in order to obtain sufficient data to be used as a standard against which other bases could be compared. In addition, one of the bases was to be used to study natural phenomena such as whistlers which are present both as electromagnetic waves and earth currents. A two thousand metre range was therefore considered adequate for these experiements and a suitable site for the transmitter was located on one farm and a site for the receiver on another.

Bases

As equipment will invariabley have to be portable, experimenters can do little better than adopt World War 1 techniques as they are proven and much technical and constructional data is available. Bayonets were normally used as earth pins during operations, but manuals illustrate earth pins made from steel rods about 20mm diam and 1.0m long. The author opted for this approach and lengths of suitable rod were obtained from the local scrap yard for about £2. One end was sharpened to a point and the other bent over to form a handle to facilitate extraction. A substantial vice and the requisite metal working equipment is necessary for shaping pins, so for experimenters not having these facilities, the best approach is to have the earth pins made by a specialist firm (see Figs. 1 and 2).

After shaping, the pins were first cleaned with a wire brush and then polished to bare metal with carborundum cloth. To prevent formation of rust while not in use the surface was lightly covered with oil — this was cleaned off and the surface rubbed down with carborundum paper to expose bright metal immediately before inserting into the soil. Each earth

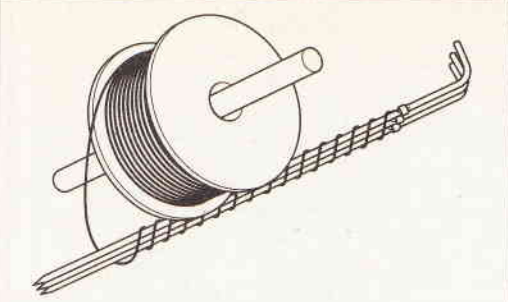


Fig. 2 Earth Pins bundled with cable drum

consists of three pins spaced 750mm apart and aligned in a plane facing the opposite earth (see Fig. 3). Automotive 27 strand cable obtained in 100m drums is used to connect the base to the equipment and the cable is attached to the individual earth pins by stainless steel hose clamps. The WW1 practice of placing a transmitter close to one earth point was adopted so that the cable extends in one direction, but this is unimportant and the transmitter/receiver can be located at any convenient place.

Copper tubes 15-20mm dia could be used, but with temporary installations, rusting is unlikely to be a problem with steel pins. Copper tube is far less durable and much more expensive than steel rod.

Earth current equipment should not be operated during electrical storms. Lightening creates enormous earth currents — they are a principal source of whistlers and other natural phenomena. A nearby strike can damage equipment and pose a serious hazard to the operator. Indeed, such currents frequently kill livestock: the animal's body and legs form a base which provides an alternative path for the electrical impulse passing through the soil.

Experimental Systems

Whilst replicating early equipment, particularly that used during WW1, it is still possible to locate areas where 50Hz pollution is tolerable. A 12V car hooter, modified by removing the diaphragm was used to replicate a buzzer transmitter, but later an asynchronous DC to AC power converter was used. This generates pulse waveforms almost identical to a power buzzer. The power converter was built around a mains transformer with centre tapped 12V windings, but a fair amount of trial and error was involved in order to generate a 1kHz note. Both devices were keyed automatically by a small geared 12V motor rotating a specially shaped cam.

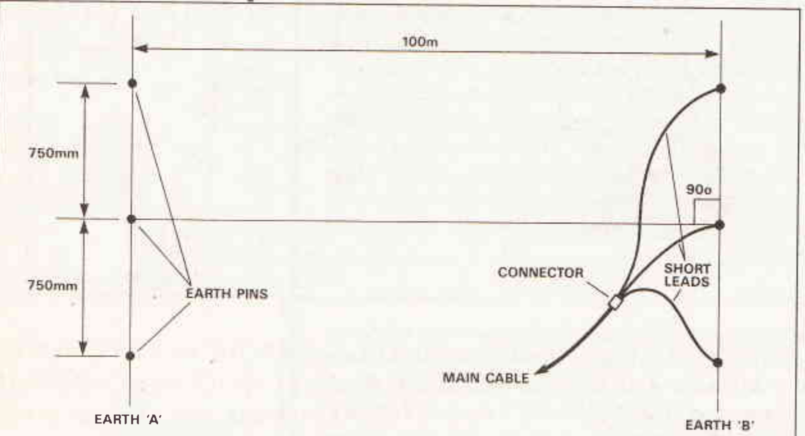


Fig. 3 Plan of a base used by the author

For most experimenters, direct speech communication makes an interesting introduction to earth current communication and a wide range of experiments are possible using ordinary audio power amplifiers (20W RMS minimum) as transmitters, and medium gain low power amplifiers as receivers.

Transmitters

At audio frequencies, the impedance of a base is about the same as its DC resistance and that of a typical 100m long base is likely to be around 200R (see Table 1) but can vary considerably according to soil type and moisture content. Some form of matching device, typically a transformer, is therefore required when ordinary domestic amplifiers designed to operate 8R loudspeakers are used as transmitters, and by the same token, a similar device is necessary to match the base to the receiver amplifier input.

The transmitter is designed to operate automatically from a 12V car battery and the technique adopted is to first record speech and tones on tape using a 4-speed battery tape recorder operating at a speed of 1⅞ips which gives a continuous playing time of 2 hours over a frequnecy range extending from 40Hz to about 10kHz. When transmitting, the recorder's audio output is increased to about 20W by using one channel of an in-car stereo booster. The low voltage output from the booster is then raised to a level suitable for feeding the base by means of a commercial transformer designed to allow domestic amplifiers with 4-16R output to be used with 70-100V distribution lines.

Ideally, the transmitter/base transformer should have a tapped high impedance winding to allow optimum matching, but as far as the author is aware no such commercial transformers are available. During early trials, the author used an old 112-240V mains transformer with a variety of low voltage taps as a matching transformer with reasonably good results: in this case the base was normally connected to the 112V tap and the amplifier output to the 9V tap. Meters were used to determine the optimum tap under various conditions. Plans to wind a special transformer on the laminations salvaged from the output transformer of an old Leak valve amplifier are underway.

A battery operated 12V PA amplifier designed for use with 70 or 100 volt distribution lines could be used as a transmitter. The base presents an almost completely resistive load, so some mismatch is unlikely to harm the amplifier, but during the first trials, current and voltage should be measured to determine the operating parameters and to make sure that the amplifier is not overloaded. The author has not tried these amplifiers, on account of their cost and through his preference to assemble his own equipment.

Receivers

With receivers having a bandwidth wide enough to accept speech frequencies, background noises originating from miscellaneous static discharges and ELF radio transmitters, are inevitable. On the other hand, 50Hz mains interference can be dramatically reduced by means of a notch filter. Fortunately most interference problems can be avoided by using frequency selective devices and communicating by tones, the simplest of course being morse code, but the potential for more sophisticated designs including digital and syntonized systems seems almost unlimited and offers tremendous scope for the amateur scientist.

High and low pass filters should be used to reduce the frequency response of wide band amplifiers. Low pass filters may also be necessary to suppress interference caused by earth currents that seem to complement VLF and ELF electromagnetic wave transmissions. Good earths are essential to ensure a base with low impedance and therefore insensitive to electric, magnetic and electromagnetic fields.

If 50Hz currents are a problem and flow at an angle greater than about 30° to the desired currents, they can usually be nulled out by re-orientating the base, but this results in a proportional reduction of the effective length of the base when receiving desired currents (Fig. 4).

The audio stages of a 15-year-old battery portable MW/LW receiver were modified by incorporating a 50Hz notch filter and adding a single extra transister stage to increase the gain. The resultant receiver retains it original strong wooden case and uses the same loudspeaker. It is light, self contained and suitable for reception of pulse waveforms, tones and speech. The transformer coupled push-pull output stage has a bandwidth well suited to this form of communication. The base is matched to the amplifier by means of an in-line microphone transformer. Ideally, a tapped matching transformer should be used, but the microphone transformer, designed for inputs of 150-600R and outputs of 10-100k, gives good results.

Using the tape recorder and 20W stereo booster as the transmitter, strong signals, well above background noise were consistantly received 2,000m down range at the receiver site and there is no doubt that the useful range is considerably greater. Remarkably, using the same receiver, signals from the car hooter were also readable and gives a good idea of the range possible with the simplest of equipment. However, the characteristic sound of the DC/AC power converter was exceptionally strong, and well able to override background noise. Bearing in mind the range of the power buzzer during WW1, signals from the power converter would almost certainly be readable at a range of 5 to 6km.

In part 3, the author discusses a tunable earth current receiver and his set up studying natural earth currents.

Table 1
OVERALL RESISTANCE OF A BASE 100 YARDS LONG

Extracted from Signals Service (France) Manual Technical Instructions No 5 Power Buzzer-Amplifier 1917

Nature of earth contacts at the end of the base	Overall Resistance in Ohms
(a) 1 bayonet in fairly damp ground	456
(b) 1 bayonet in very wet ground	455
(c) 2 bayonets 1 yard apart	262
(d) 3 bayonets 1 yard apart	187
(e) 1 earth mat 12½′×2′ buried 4′ deep in very damp ground	89
(f) 1 four-gallon petrol tin buried in fairly damp ground	333
(g) as (f) but in very damp ground	246

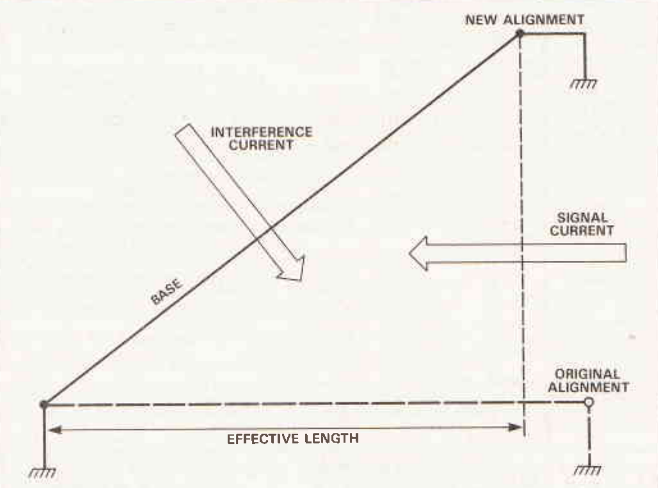


Fig. 4 Nulling of 50Hz currents

ELEMENTS OF RADIO

Part 1

In the first part of our new excursion into the world of radio, John Linsley Hood introduces basic receiver techniques

Simple as it might seem, if you hang up a piece of wire and connect it to ground through a small inductor (to get rid of the inevitable AC mains pick up), then connect an RF millivoltmeter across the choke, you'd find that somewhere between 20 and 50mV of RF signals had been picked up out of thin air by this 'aerial'.

This voltage actually consists of a huge number of radio signals, jostling each other for precedence. Some of these, individually, would be quite large, up to perhaps 20mV, others would be vanishingly small — a tenth of a microvolt or less — and this gives us the two major requirements for a successful system: selectivity and sensitivity.

Tuned Circuits

In earlier times, the only way available to select the chosen one, from this melee of available signals, was a parallel tuned circuit of the kind shown in Fig. 1. The sharpness of tuning of this LC circuit depends on its *Q* or *circuit magnification factor*. This can be thought of as the extent to which the voltage produced across the circuit by the tuned signal was greater than that which would have arisen just across the effective series resistance of the circuit, r.

The value of a tuned circuit's Q, and the bandwidth of its selectivity curve, at the −3dB points, is given by

$$Q = \frac{1}{r}\sqrt{\frac{L}{C}} \quad \text{and} \quad BW = \frac{f_0}{Q}$$

which implies that, for any coil/capacitor layout, the larger the ratio between the inductance and the capacitance, and the smaller the total resistive losses in the system (generally represented by a notional resistor in series with the coil) the higher the Q and the sharper the tuning.

Selectivity curves given by three tuned circuits, having differing values of Q are shown in Fig. 2. Two things are obvious from this. First, the ability of a tuned circuit to select a chosen signal and reject an unwanted one, say 10kHz away from it, decreases linearly as the tuned frequency is increased. Second, particularly for short-wave use (3 to 100MHz), very high values of Q are needed if such a radio is to be of any practical use, for any but the strongest of signals.

Methods Of Increasing Q

Unfortunately, attempting to make the Q of a tuned circuit higher, by making the inductance large and the capacitance small, is defeated by the inevitable presence of distributed stray capacitance, from turn to turn within the coil, so that typically, the best Q of a tuned circuit is usually given when these stray capacitances are swamped by some external capacitance, typically in the range 50 to 100pF.

Using low RF resistance wire (multi-strand *Litz* or heavy gauge single strand) will help to keep the winding losses down a bit, but the most crafty technique — evolved in the early days of radio — for achieving this aim is to feed back a bit of RF energy from the output of a subsequent amplifying stage to make up for the resistive losses in the tuned circuit.

This technique, a form of positive feedback, is called *reaction* or *regeneration*, and a typical one valve radio receiver using this system is shown in Fig. 3. In operation, the amount of RF fed back into the circuit should be gradually increased, by adjusting the value of C4 upwards, until the whole circuit goes into oscillation; then it should be slackened off just enough to stop the continuous whistle the oscillation produces.

With a delicate touch, tuned circuit Q values of up to 20,000 or so can be achieved, which will fish microscopic signals out of nowhere, and give a very useful degree of inter-signal separation. However, the problem is that if tuning is altered, the reaction control setting has to be readjusted too, which makes tuning across the band rather fiddly.

On the other hand, this technique *does* work, and the circuit of Fig. 4 is offered as a contemporary equivalent, for those who would like to try it out. This uses a FET as a detector, in which regeneration is applied using Colpitts-type feedback, based on the gate-source capacitance of Q1, together with C4. In use, variable capacitor C5 is gradually reduced in value to bring the circuit just to the verge of oscillation, which is the condition of greatest signal sensitivity.

Because the sort of AF signal output possible from a single transistor is a good bit less than that from a valve, a further transistor, Q2, is included as an AF amplifier stage. A very rough prototype of this circuit brought in signals from the USA and India, at good listening strength, on a 4-foot wire aerial. Most FETs should work as Q1, if a suitable value for RV1 is used.

Super-regenerative Systems

Although regenerative feedback is a simple and effective way of increasing the Q of the input tuned

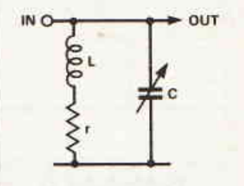


Fig. 1 Simple parallel tuned circuit

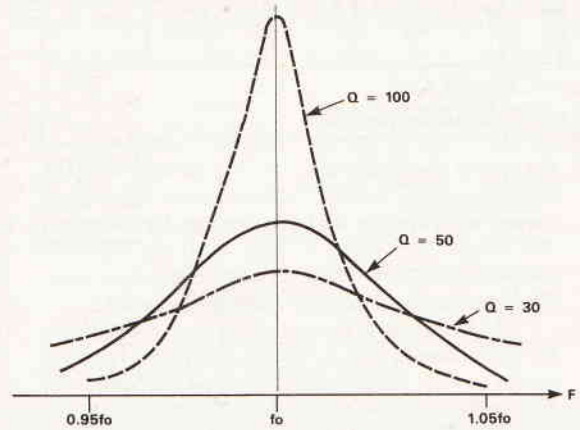


Fig. 2 Effect of Q on selectivity curves of tuned circuits

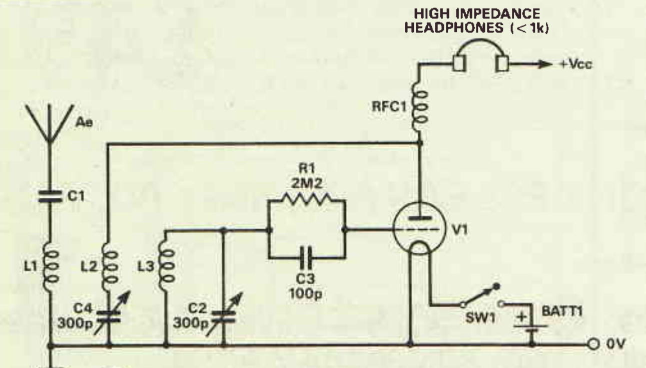


Fig. 3 One valve radio, using regeneration to increase sensitivity and selectivity

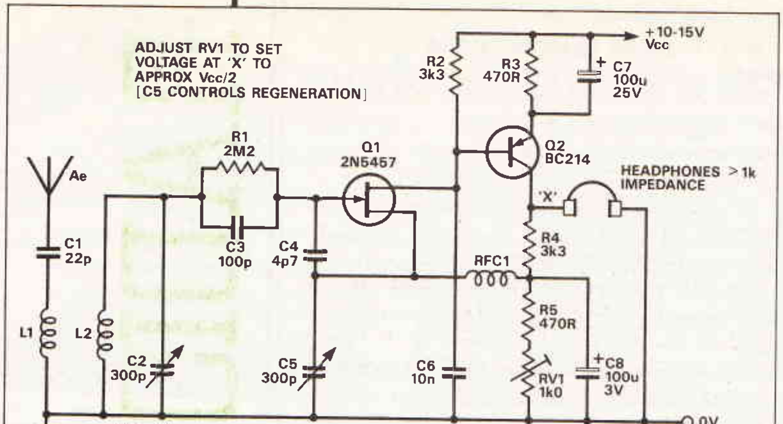


Fig. 4 Two transistor radio receiver using regeneration

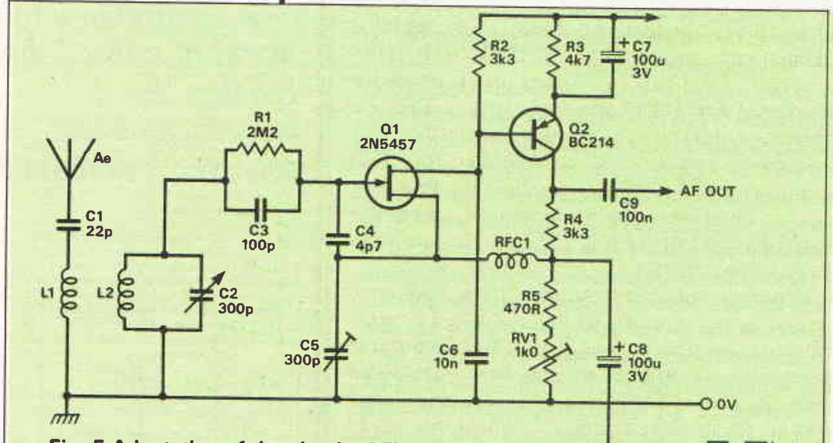


Fig. 5 Adaptation of the circuit of Fig. 4 as a super-regen system

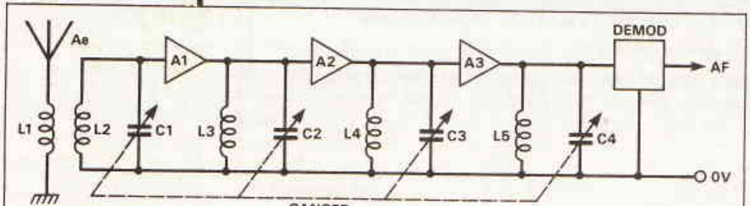


Fig. 6 Simple tuned radio frequency amplifier

circuit, it is a bit tiresome to use, and the receiver can't be swept rapidly through the tuning band. The *super-regenerative* system, on the other hand, is based on the idea that it takes a little while for a tuned circuit/amplifier set-up to burst into oscillation, even if a large excess of positive feedback is applied.

So, if the gain of the system is lowered just before the circuit breaks into oscillation, then raised again a brief time later, it's possible to have all the benefits of a regenerative circuit wihout the fiddle of regeneration control readjustment. This scheme does work, and is called a super-regenerative, or super-regen, receiver. It's widely used in low cost VHF receivers, such as citizens' band units. Various techniques are adopted for damping or quenching the oscillation, but the most common is simply to apply a squarewave signal to some point which will control the circuit gain, such as transistor Q1's source in the circuit of Fig. 4. This allows control of source voltage, leading to the kind of circuit layout shown in Fig. 5.

Because the applied quenching signal appears as an output along with the wanted signal, it is necessary to ensure the frequency of the squarewave is above audio frequency or, at least, above the cut-off frequency of any subsequent audio low-pass filter. Generally, the quench waveform frequency will be in the range 20kHz to 100kHz, but the lower the frequency the better the circuit performance; because it gives the feedback a longer time to build up.

Various quench waveforms can be used, but there is not a lot of difference in the final performance, so a straightforward squarewave, which is easy to generate, is the simplest option.

A snag with all super-regen systems is that they generate a very loud inter-signal hiss. There are two main reasons for this. First, random thermal noise in the tuned circuit is amplified in lieu of any other signal. Second, any such system (even a simple receiver with a reaction control) in oscillation, will itself radiate noise or whistles on the frequency to which it is tuned — these can be a nuisance to other adjacent receivers.

Tuned Radio Frequency Receivers

A simpler method of obtaining required gain and selectivity from a receiver is to connect a series of tuned ciruit and amplifier stages one after another, as shown in Fig. 6.

Then, if the sharpness of tuning of a single tuned circuit (due to its Q) is such that it allows a discrimination between wanted and adjacent unwanted signals of 4.5:1, and the amplifier stage has a gain of 10, two identical stages in cascade give a selectivity ratio of 20:1 and a gain of 100. Similarly, four cascaded stages give a gain of 10,000 and a rejection of the unwanted signal of 400:1.

Although appearing to solve the problems of radio reception, there are two problems here: first, the four stages all require individual tuning — and it's not possible to buy a four-gang tuning condenser. Second, the nature of the selectivity curve given by a normal single LC tuned circuit causes a loss of broadcast signal sidebands and the received signal will lack in treble.

The reason for this is that if a transmitted signal carrier frequency is modulated with an audio signal, the final broadcast signal will consist of a spectrum of RF components, with the carrier frequency sitting between two groups of sum and difference frequencies (that is, signal frequency minus modulation frequency, and signal frequency plus modulation frequency). So, if the selectivity gave a response which was down to 10% at 8kHz on either side of the tuned frequency, an 8kHz modulation would also be recovered at only one tenth of its transmitted level.

There are two simple ways of increasing bandwidth: by staggering the tuning of successive circuits; by using bandpass coupling, which is the more elegant approach. In this, a second tuned circuit is

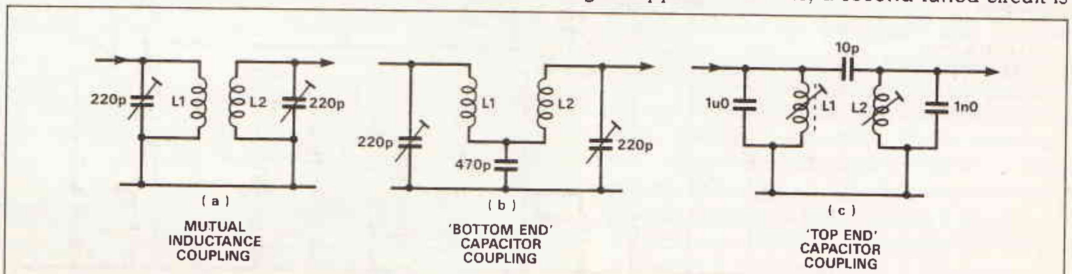


Fig. 7 Band-pass tuned circuit systems (a) with mutual inductance coupling (b) with bottom-end capacitor coupling (c) with top-end capacitor coupling

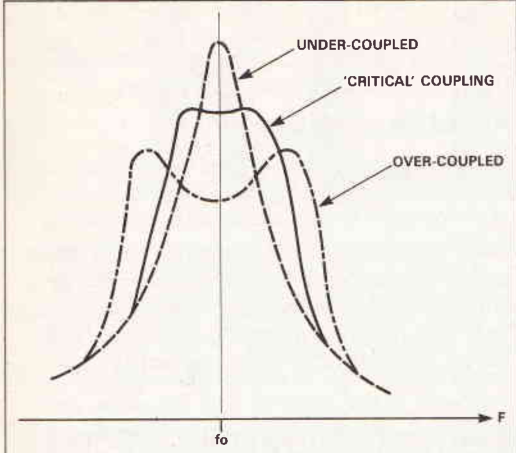


Fig. 8 Band-pass selectivity curves

allowed to steal some energy from the first, at its frequency of resonance, thereby flattening the top of the response curve.

Bandpass Tuned Circuits

Band-pass coupled tuning circuits are shown in Fig. 7. These layouts give a variety of selectivity curves, of the kinds shown in Fig. 8, depending on the tightness with which they are coupled together — either by some degree of mutual inductance or, if this is impracticable, by capacitive coupling.

Clearly, if the frequency response of the tuned circuit has a flat top around the required signal frequency, a whole string of stages using this kind of tuning can be cascaded without loss of sideband response, up to the point at which the gain starts to fall off.

This is very nearly an ideal answer to the need for selectivity without loss of higher AF signal frequencies. The problem is, of course, that it is quite impracticable to tune four or more such bandpass circuits, simultaneously retaining the precise value of critical coupling needed for a flat-topped response.

The Superhet

A neat way of getting round the need to re-tune a whole string of bandpass coupled circuits was invented, in the 1920s, by the same ingenious Major Armstrong of the US Army who developed the super-regen system.

This scheme, called a *supersonic heterodyne* (*superhet* for short), leaves the RF gain and selectivity producing circuits pre-tuned to some convenient spare frequency. This spare frequency is known as the *intermediate frequency* or IF, often 455kHz. It is then a relatively simple matter of altering the frequency of the wanted incoming signal so that it's at this chosen IF value.

The superhet scheme is shown in Fig. 9, where the incoming signal is mixed with a locally generated RF oscillation. The mixer is sometimes known as a frequency changer. Almost any device will work in this position, provided its transfer characteristic is sufficiently non-linear.

Non-linearity in the frequency changer generates sum and difference intermodulation products (the bane of hifi amplifier design), and if the local oscillator frequency is chosen correctly, one or other of these output frequencies will be centred on the IF frequency and the signal will then be amplified.

Of course, the snag with this scheme is that unwanted signals can creep in. If we take an example of a wanted signal at 1MHz, an IF of 455kHz, and a local oscillator frequency of 1.455MHz; the signal at the difference frequency (1.455MHz - 455kHz) is the one wanted. Fine, so far — but it's also possible for an unwanted signal at the sum frequency (1.455MHz + 455kHz = 1.91MHz) to generate exactly the same IF frequency, and it would be amplified too. This spurious reception frequency is called the *image* or *second channel* frequency, to distinguish it from the normal adjacent channel breakthrough due simply to inadequate selectivity.

The only way to get around image frequency breakthrough is by ensuring that there is adequate selectivity in the path between aerial and the input to the frequency changer. This is easy enough to do for frequencies up to a few MHz (with a 455kHz IF) but at higher signal frequencies adequate pre-mixer selectivity becomes increasingly difficult, so higher IF frequencies, say 1.2MHz, or even 10.7MHz, are often used.

The RF Stage

In addition to the problem of image frequency interference there is also the problem that frequency changer stages are usually much more noisy, and

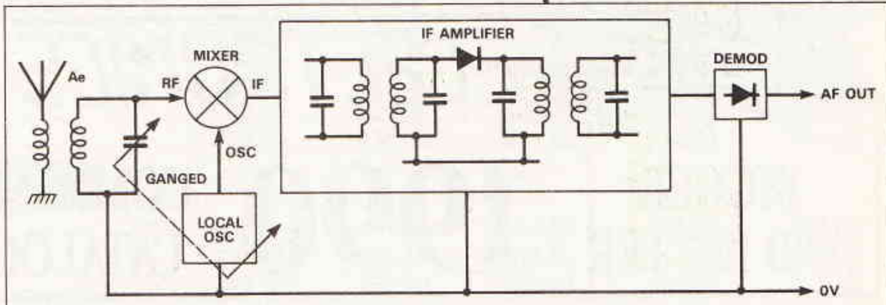


Fig. 9 Basic layout of superhet receiver

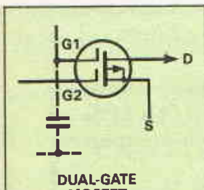


Fig. 10 Dual-gate RF MOSFET

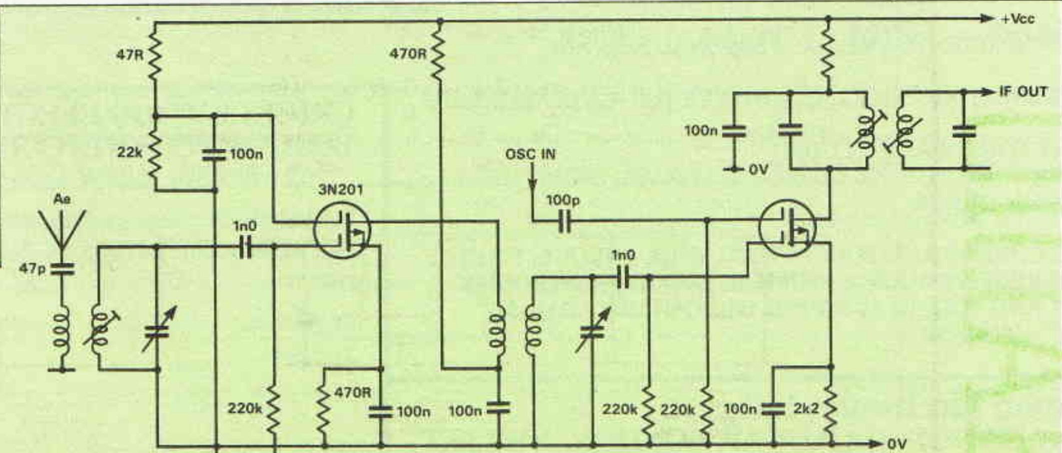


Fig. 11 RF/mixer system using dual-gate MOSFETs

have a lower stage gain than a normal simple gain stage. Consequently in high quality receivers, and systems like AM car radios, there is almost always one or more tuned RF stages, partly to improve image frequency rejection, and partly to improve the signal-to-noise ratio of the circuit as a whole.

Although there is a variety of devices which can be used as RF amplifiers — bipolar transistors, junction FETs, and MOSFETs — the simplest arrangement is that of the dual-gate MOSFET. This kind of device was designed specifically for use as an RF amplifier and features a second gate (G2), sitting between the signal gate (G1) and the drain, as shown in Fig. 10.

Provided this gate electrode is decoupled to the ground (0V) line, the input gate is then effectively screened from the drain. The normal residual feedback capacitances in a dual-gate MOSFET are of the order of 0.2-0.5pF — low enough to avoid instability due to unwanted RF feedback. On the other hand, the normal 2-5pF collector-base, or drain-gate, capacitance of the bipolar transistor or conventional FET may cause instability.

Without allowing the ultimate in performance a dual-gate MOSFET also makes a very satisfactory superhet frequency changer stage, leading to the type of circuit shown in Fig. 11, with dual-gate MOSFETs used both as RF amplifier and mixer stages.

IF Amplifier Stages

This is where the bandpass coupled tuned circuit, of the general type shown in Fig. 7, comes into its own. As it is unnecessary to retune these after initial setting up, it's theoretically possible to have as many IF stages (with as much IF gain and selectivity) as needed, bearing in mind, of course, that they will also amplify noise. Some difficulties with RF instability may, however, be experienced, too.

In general, though, IF amplification does give a useful answer to the need for both selectivity and sensitivity, and a practical IF amplifier/demodulator circuit using easily obtained 455kHz coils is shown in Fig. 12.

In the next article, residual problems with superhet systems, methods of obtaining better selectivity, automatic gain control, and some practical circuit designs are discussed.

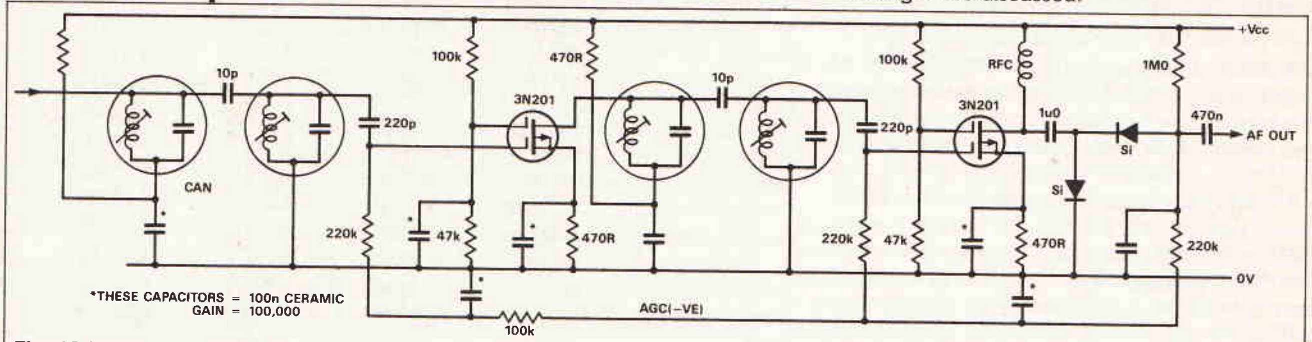


Fig. 12 Practical high quality 455kHz IF strip with AGC

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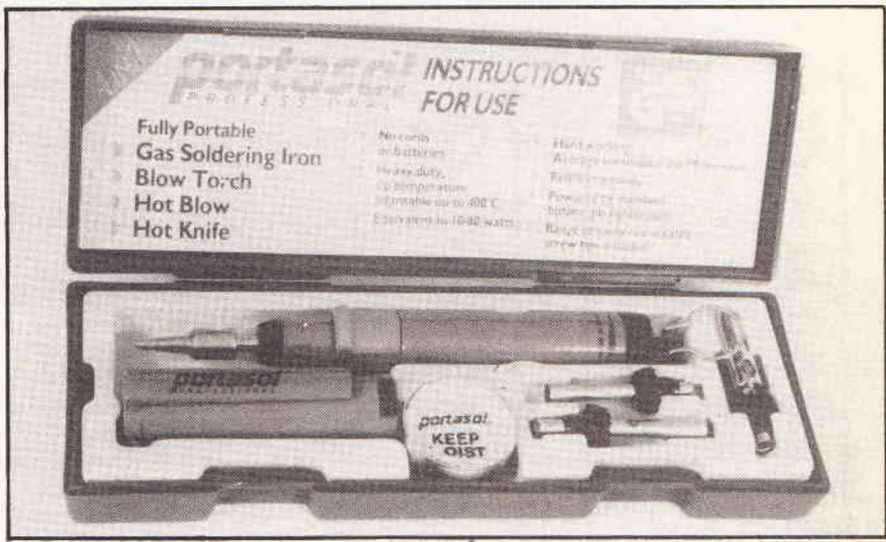

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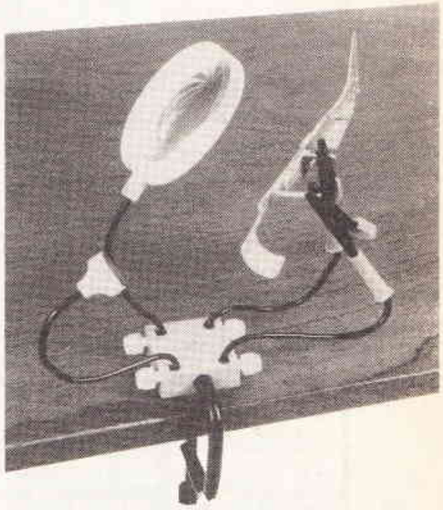

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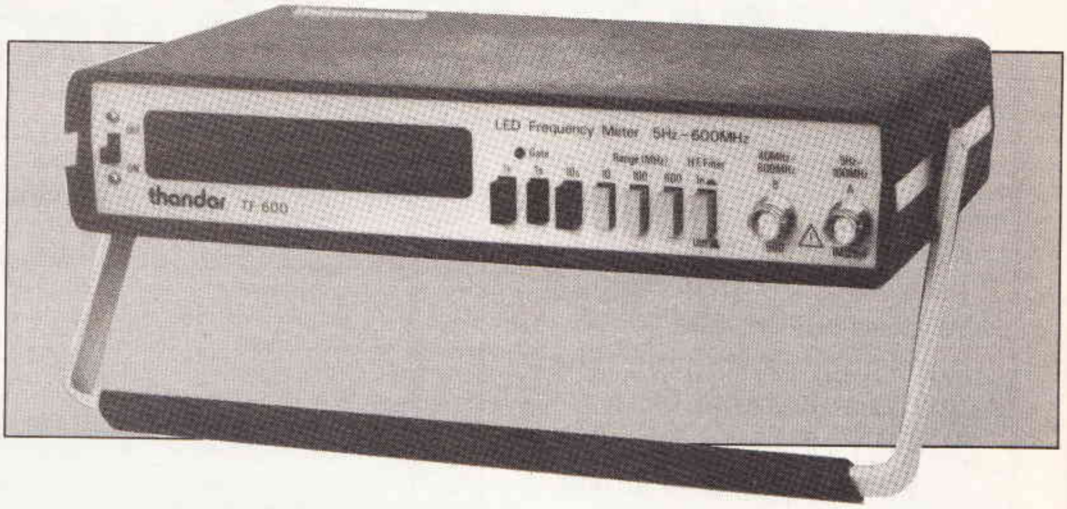


Mike Barwise takes us on to frequency meters and power supplies

TEST GEAR

The next item on our list of test gear is the frequency meter. The function of this is fairly obvious: it measures frequency. Frequency meters range from about £80 to £500 in price. At the low price end (up to about £250), they are all much the same in mechanism. What you pay extra for is improved precision. These instruments work by counting pulses during a well defined window.

A window is a period of time in this context. A counter clocked at the frequency of the incoming waveform is enabled for a specific time, and then disabled again. The terminal count is a direct measure of the number of cycles in a given time, so the frequency can be calculated. Most instruments of this type use single-chip solutions these days, and the upper frequency limit of these is quite low (around 20MHz). It is normal to offer an upper frequency limit of 100-200MHz, so a device called a prescaler is used. This is a clever system based on the phase-locked-loop which divides any input frequency within a given range by a constant factor. This is the first thing the measured signal hits when it enters the frequency meter, so the frequency at the counter is always one tenth of the input frequency. This works fine, but it increases the time taken to get a reading. At very low input frequencies, this can be a bit of a bore: maybe waiting 10 sec, or even 100 sec (nearly two minutes!) for a reading. You can't have everything! Much more expensive frequency meters use all sorts of different techniques, but you won't be able to afford them anyway, so we will leave them out for the moment.

Power Supplies

The last item on our list of test gear is the bench power supply. Most people take power supplies and power distribution for granted, even when designing printed circuits for commercial equipment. This is a big mistake. Inadequate power supplies are possibly the most important cause of poor circuit performance.

Power supplies have three main characteristics: stability, line regulation and load regulation. Stability is a measure of ripple (short-term output variation e.g. 100mV to 50Hz variation on top of a 10V supply) and long-term drift. If the output is at 10V on switch-on, will it be at 10V half an hour later, when the power supply unit or PSU has warmed up?

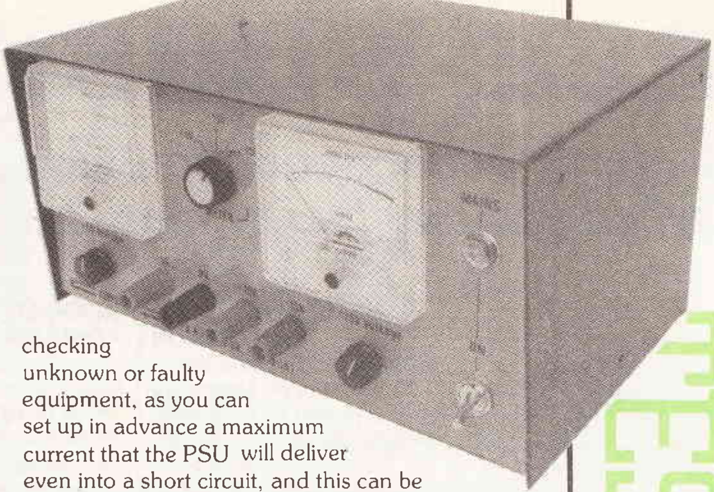
Line regulation is a measure of how variations in input voltage are reflected at the output (good line regulation implies that a large input voltage change will cause little or no output voltage change). Load regulation is a measure of how much the nominal output voltage changes for widely differing load circuits.

The PSU regulation requirements for different types of circuits vary widely. The majority of audio equipment (even very high quality) requires a power supply reasonably free of mains hum (50Hz or 100Hz ripple) but can tolerate quite large changes in supply voltage without noticeable loss of peformance. Fast digital circuitry of the TTL and ECL types (current driven devices with finite logic thresholds) require a much tighter tolerance of supply voltage for proper operation. CMOS logic (voltage operated with supply-proportional logic thresholds) has a more relaxed requirement. Measurement systems which use precise reference voltages such as A/D and D/A converters need probably the tightest tolerances of any common system. The majority of applications thus need power supplies with greater stability and regulation than is normally available from a mains transformer, rectifier and smoothing capacitor. A technique called *linear regulation* is frequently used to improve conditions. The linear regulator is effectively a stable DC amplifier which amplifies a very precise and elecrically quiet voltage, which is frequently derived from a zener diode. The output from the transformer, rectifier and capacitor is passed to the linear regulator for finishing off, and levels of ripple and line regulation better than 0.01%, and load regulation better than 0.1% are easily obtainable. Another kind of power supply is the switch mode PSU. This is based on the principle that transformers can be more efficient and more compact when working at higher frequencies than the 50Hz of UK mains. Efficiencies of 85%-97% are attainable, compared with 45%-55% for linear (mains frequency) power supplies. The switch mode PSU basically rectifies and smooths the mains, recreates a new AC using an oscillator running at about 10-40KHz, passes this through a transformer of much smaller proportions and then rectifies, smooths and *post-regulates* the resulting low AC voltage. Two alternative methods of regulation are used. The first is the use of linear regulators as just described, and the second is *pulse width modulation* (PWM). This works rather like the domestic light dimmer switch. The voltage is stabilised by sending longer or shorter pulses of current into a large capacitor so that the voltage across it is constant as the current drawn from it by changing load varies.

PWM switch mode power supplies have the general problem that their outputs contain a lot of high frequency noise. This is due to the switching transients in the PWM system. Also, for small load currents (<5% of maximum) there is a tendency to loss of regulation: the output voltage may rise to a degree which could damage your circuits. This is due to the limitations of the PWM system: its inability to provide short enough pulses when little current is being drawn. A high power low value resistor permanently across the output normlly protects your circuits from this hazard, but efficiency is obviously considerably reduced by this wasted current. Linear post-regulation does not suffer from this problem, but the requirement for a minimum voltage differential between the input and output to retain regulation (a bit more than the voltage of the reference) causes the post-regulator to dissipate quite a high percentage of the available power when you want low output voltages. 5V supplies of this type are therefore generally less efficient than, for example, 12v or 15v supplies.

For general experimental use (hobby and development work included) the linear regulated mains frequency power supply is probably the most useful. Typical specifications to cover most jobs would be one output 0-30V at up to 2A, plus two independent 0-15V at about 500mA max. Each of the three should be *floating* (not referenced to ground) to allow you to connect them in series. You can then create a ±15V supply by temporarily referencing the junction of the two 15V supplies to ground.

You can buy very neat linear bench PSUs today, which have analogue or digital meters built in, and have current limit control. This is quite useful when



checking unknown or faulty equipment, as you can set up in advance a maximum current that the PSU will deliver even into a short circuit, and this can be set to be quite small. Some of these PSUs also have remote referencing. A second set of terminals connects via a second pair of leads to the power input of the circuit you are working on. Any voltage drop in the first (power carrying) leads is compensated for by the PSU raising its output voltage a bit. This can be very useful under high current conditions.

However, you can build your own linear PSU quite easily, and this is one area where you can save yourself a great deal of money. Several pieces of DIY test gear will feature alongside this series as we proceed, so keep your eyes on this space.

There are obviously many specialised items of test gear we have not discussed. We have covered the basics: the gear everyone needs on the bench. From next month, we will look at a range of measurement and test scenarios, ranging from the elementary to the pretty abstruse, and we will bring to bear the instruments discussed.

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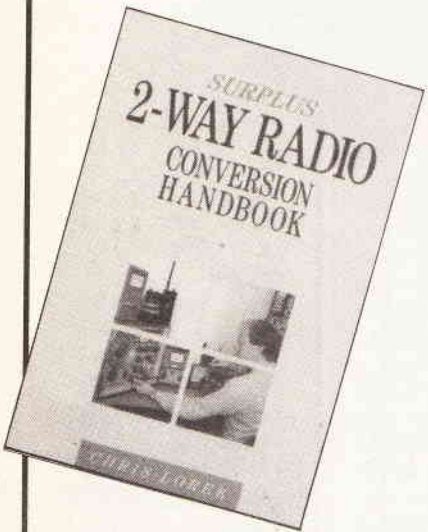

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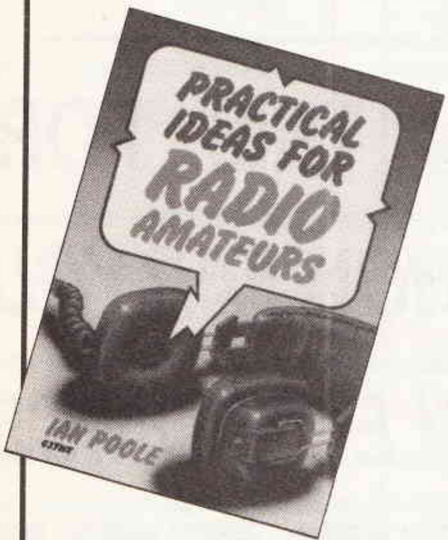

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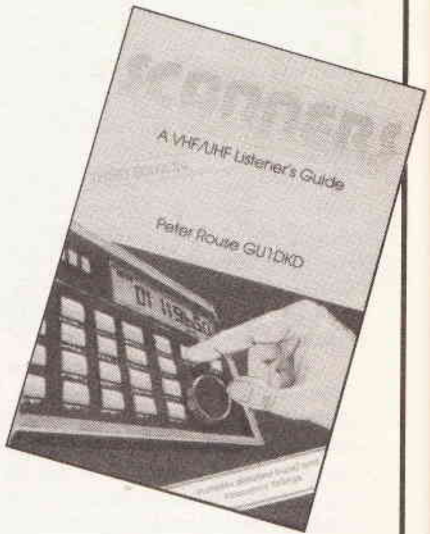

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E8906-4	MIDI converter control	M
E8906-5	AF signal generator	G
E8906-6	Mini bleeper	C
E8906-7	Caravan heater controller	G
E8907-1	MIDI Patch Bay	G
E8907-2	Priority Quiz Switch	E
E8907-3	Camera Trigger Infra-reds (2 boards)	G
E8907-4	Aerial Amplifier main board	E
E8907-5	Aerial Amplifier power supply	E
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E8912-3	Slide/Tape Synch	E
E8912-4	Pedal Power	L
E8912-5	Digital Noise Generator	K
E9001-1	20 metre Receiver	J
E9001-2	Wavemaker FG	L
E9001-3	Motorcycle Intercom	F
E9001-4	Low Voltage Alarm	C
E9002-1	EPROM Emulator	N
E9002-2	Superscope Mother Board	M
E9002-3	Superscope CRT Driver Board	K
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TECH TIPS

A collection of circuits both new, from the ingenious readers of ETI, and old, culled from our vast archives

Intelligent Intercom

Dominic Banham
Hertfordshire

As can be seen from the circuit diagram, the circuitry around ICs 1 to 3 is divided into two identical channels. It is easiest to see how the system works if you look at the operation of only one channel, that consisting of IC1a,c, IC2a,c, and IC3a,c.

IC1a forms a conventional inverting amplifier with the gain determined by R1 and the remote speaker impedance.

The amplified audio signal from IC1a, which is arranged as a comparator. Under quiescent conditions its non-inverting input is held at a slightly lower voltage than its inverting input by potential divider RV2/R6. Negative-going peaks in the input signal will, if of sufficient amplitude as determined by the setting of RV2, force the inverting input lower than the non-inverting (which remains static due to the low-pass filter action of RV2 and C10) thus causing IC1c output to pulse high. The pulses charge C12 via D1 and IC2a, which is normally in the closed position. The time constant C12-R8 is chosen so that a normal stream of speech at the remote station will keep the inputs of IC3a high, whereas they will go low again when the signal ceases. This high level caused by the charging of C12 drives the output of IC3a low.

This has two effects. Firstly, it causes the output of IC3c to go high, closing switch IC2a and energising RLA1 via Q1. This allows the audio signal from IC1a to pass to the power amplifier IC4 via IC2a and C1, RV1, and on to the local speaker LS1, thus completing the speech path in this direction.

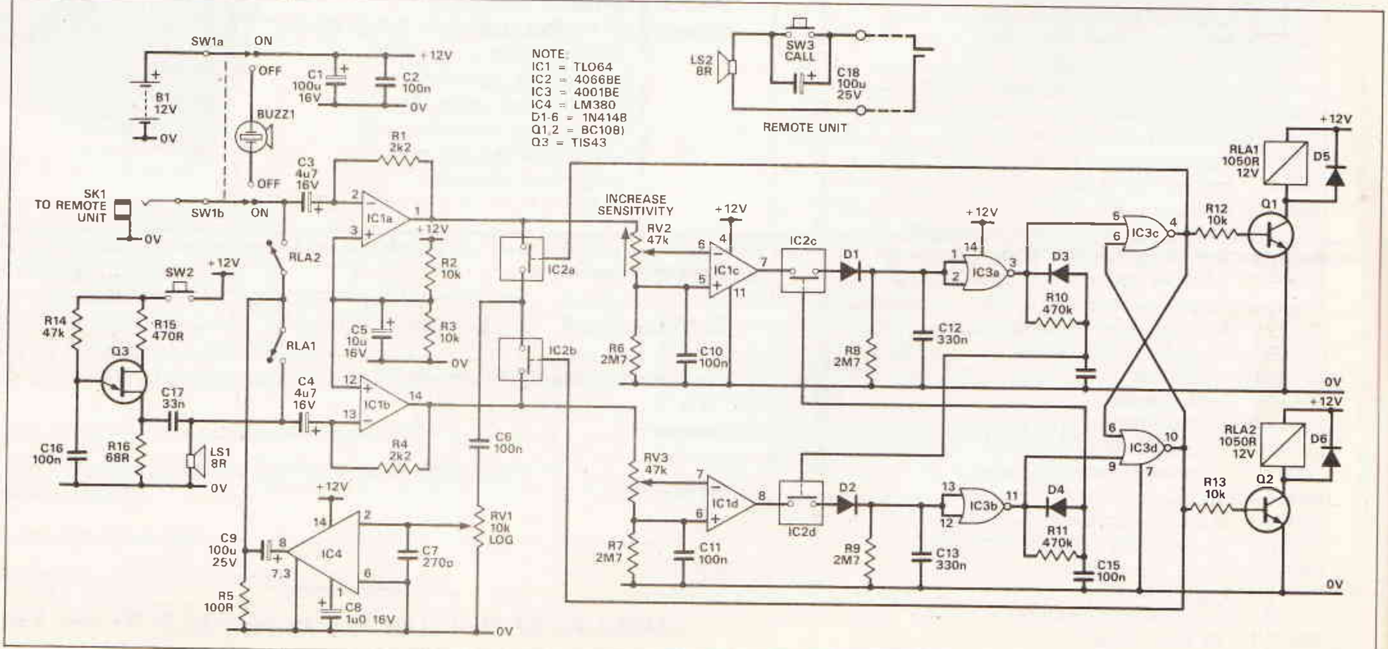
Simultaneously, the low output of IC3a rapidly discharges C14 via D3, thus opening switch IC2d. This disables the lower channel of the circuit, which would otherwise be operated by the amplified signal appearing at LS1. The cross-coupling between IC3c and d is not strictly necessary but prevents both relays operating simultaneously as a result of a power-supply glitch. (The system has operated perfectly well without this coupling).

When the input signal ceases, the output of IC3a returns to a high level, disabling IC2a and the relay and so disconnecting the speech path. The network R10/D3/C14 is included to introduce a short delay between the relay being de-energised and the other channel being re-enabled. This gives the relay contacts and IC1b time to settle down (some relays open rather slowly).

The other channel, using IC1d, works in exactly the same way as described. A simple unijunction oscillator built around Q3 is provided, enabled by SW2, to provide a calling tone to the remote station by injecting it into the local input. When switch SW1 is in the off position, calling from the remote station is provided by BUZZ1. Pressing SW3 (on the remote unit) completes a DC path to ground via LS2 and sounds the buzzer. Calling could be provided by the Q3 oscillator, but on the prototype the extra switching involved was not thought worthwhile and the buzzer seemed a simpler solution. The system of using Q3 and the buzzer was chosen in preference to the feedback systems often found in intercoms because it provides a louder and more strident noise and is less susceptible to variation with supply voltage. The latter is provided by B1 which in the prototype was a stack of eight AA cells, which are more economical than the use of a PP3 (although this is feasible), and are better able to cope with the peak current demand which is 300-500mA on strong signals. Quiescent current is about 10mA and in the off state only leakage through the remote unit's capacitor is drawn.

In the prototype, SW1b was included to prevent reverse-biasing of C3. If this is replaced by a reversible type then SW1b may be omitted and a single-pole switch used for SW1.

Finally, note that RLA1, RLA2 are reed relays. The mechanical noise of the conventional type will cause trouble if they are placed too near LS1!



Pressure Mat

David Hills
Gwent

The following shows a cheap and easy method of making pressure mats for alarm systems, (it could even be used with the Radio Transmitter alarm — published in the January issue).

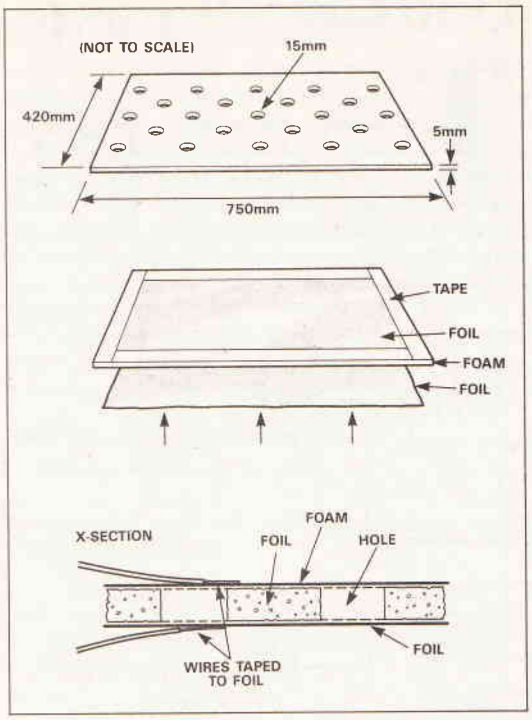
A piece of 5mm foam (the type used in furniture) is cut to about 750mm by about 420mm as shown. A series of holes about 15mm in diameter are cut in the foam as shown in the diagram. A few hundred holes should suffice.

The next stage is to tape a piece of aluminum cooking foil (around 720mm by 400mm) to either side of the foam as shown:

A wire is then taped to each piece of foil to complete the pressure mat.

When an intruder stands on the mat, the foam is compressed and a contact is made between the two pieces of foil so triggering an alarm or maybe even opening a door.

The above mats have been used under carpets for a number of years quite successfully and they can be 'custom built' to suit any application.



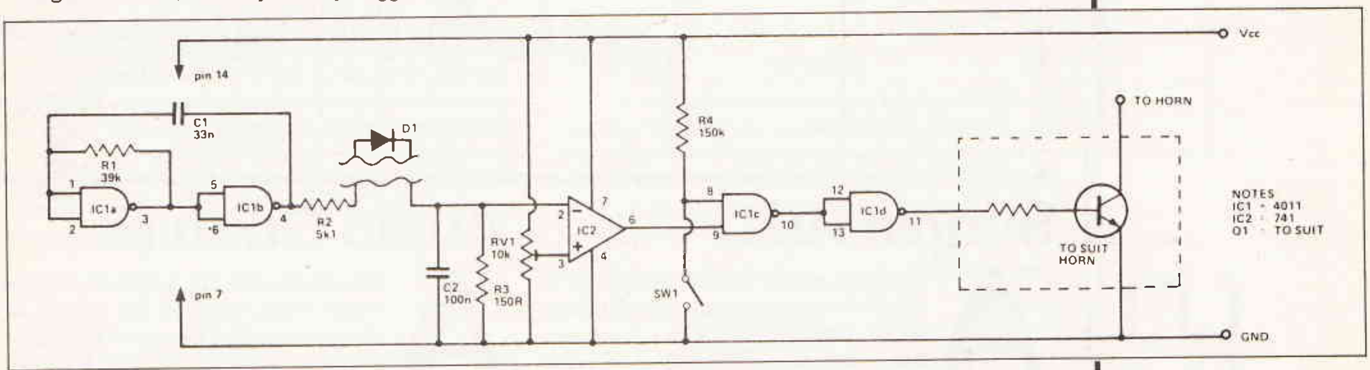
Motorbike Protector

Many of the accessories fitted to a motorbike can be valuable and yet disturbingly easily removed by a thief. A top-box may be lockable but can easily be removed complete.

This circuit will protect such accessories. Diode D1 is mounted inside the box or other accessory and two leads are run to the rest of the circuit, mounted near to the horn. Gates IC1a and IC1b form an oscillator which charges C2 through D1 and R2. The voltage on C2 (normally nearly V_{CC}) is fed to comparator IC2.

If D1 is removed from circuit by cutting the leads, C2 discharges through R3 and the comparator is triggered. However, if an enterprising thief tries to bypass the alarm by shorting the leads, the voltage on C2 falls to about $\frac{1}{2}V_{CC}$ and again the comparator is triggered.

SW1 (which should be well concealed) disables the alarm which will otherwise sound the horn if triggered.

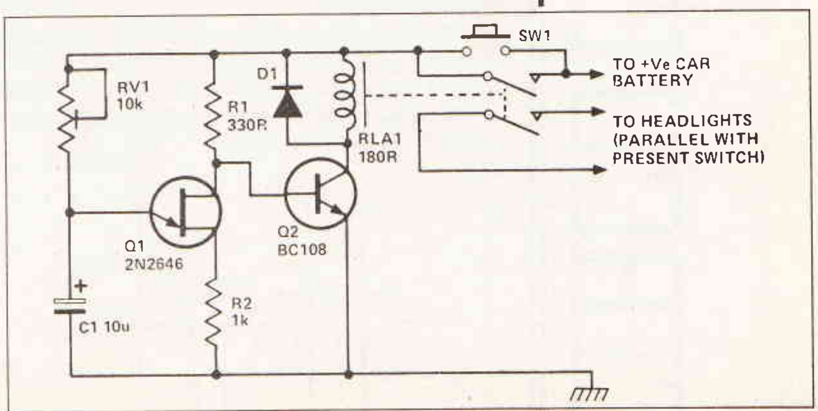


Headlight Delay

This circuit will operate a car's headlights for a predetermined time to light up the driveway or path after the driver has left the car, thus enabling him (or her) to open the front door without knocking over the milk bottles.

SW1 is pushed and Q2 is turned on closing the relay and turning on the car's headlights. C1 begins to charge through RV1 until Q1 turns on, turning Q2 off. The relay will then open switching off both the lights and the unit.

The delay is governed by the time taken for the capacitor to charge, which is about one minute.



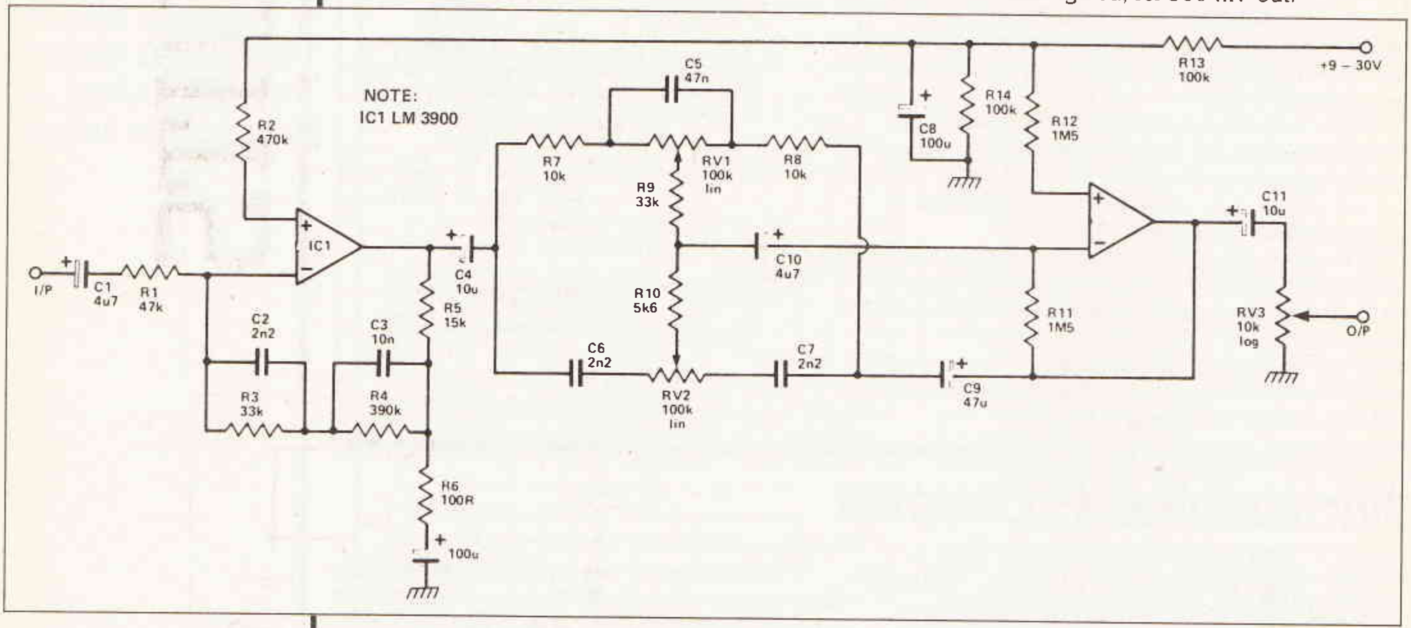
One Chip Preamp

The circuit shown utilises the four Norton op-amps contained within an LM3900 to produce a high quality stereo preamp, catering for magnetic cartridges.

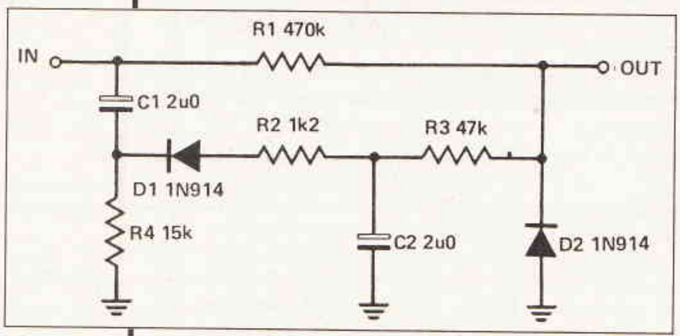
IC1 is used in the inverting mode. Signals from the cartridge are fed via the block capacitor and R1 to the inverting input. R1 defines the input impedance and provides the right damping for the cartridge.

R5 and R6 define the midband gain of the stage whilst the network R3, R4, C2 and C3 provide the required RIAA equalisation. From here the equalised signal is fed to a standard Baxendall tone control network built IC2. This requires little comment although it should be noted that individual volume controls are employed for each channel. This reduces crosstalk between channels and is cheaper in that only two single gang potentiometers are used.

Overall distortion is below 0.1% and a s/n ratio of −67dB unweighted, ref 500 mV out.



A Compressor



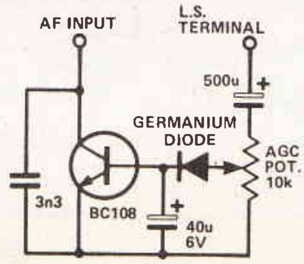
This simple compressor is very effective when tape recording from the speaker terminals of a receiver.

Input can vary anywhere from 200mV to six volts and the output will remain very close to five millivolts. Attack time is approximately three milliseconds and release time is approximately one hundred milliseconds. The diodes should be high back resistance types; 1N914s should be suitable.

Simple AGC

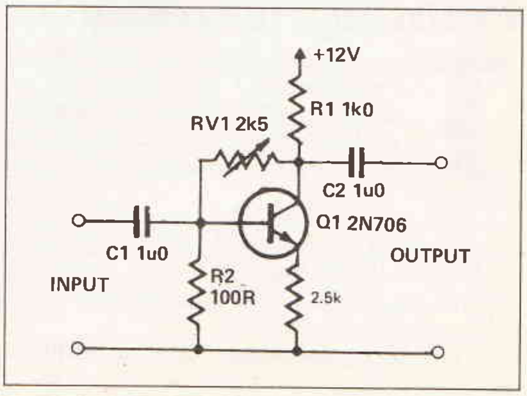
Audio derived automatic gain control is one of the simplest methods of obtaining signal compression in a radio receiver. It is of particular value with short wave receivers used in areas where deep fading is prevalent.

In use, the main volume control should be set for the desired signal strength whilst the radio is tuned to a weak station, the radio is then tuned to a strong station and the AGC potentiometer is adjusted to a comfortable listening volume.



Audio Doubler

Audio frequencies may be doubled by this circuit which relies on the non-linear characteristic of a transistor to provide half-wave rectification. R1 is a feedback control and is adjusted to obtain a pure output waveform.

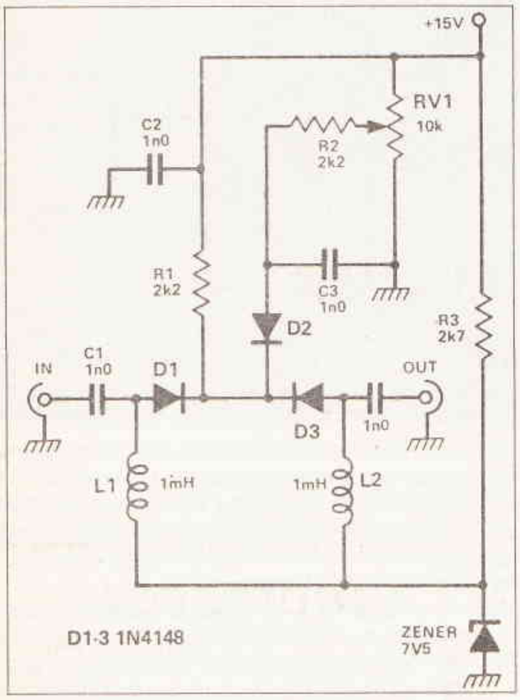


Variable RF Attenuator

This circuit can provide variable RF attenuation from 1dB to 40dB.

If intended for use up to UHF, the components should be mounted in a shielded enclosure and feedthrough capacitors used for C2 and C3. Leads must be kept short. Low capacitance high speed diodes are recommended.

The potentiometer can be mounted remotely if desired, along with R3 and the zener.



Noise Limiter

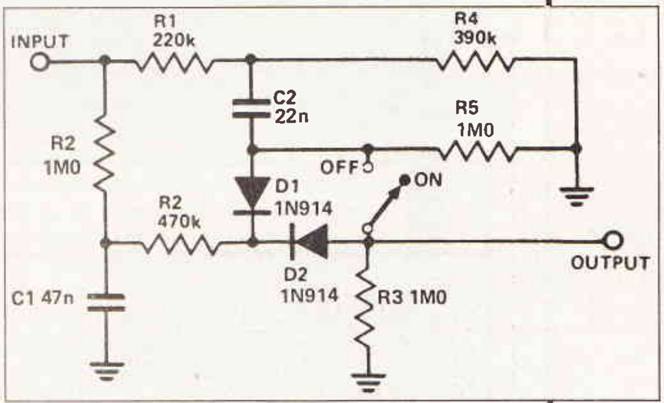
Noise pulse interference from motor vehicle ignition systems (another form of pollution — cars just can't win) can render a communications or shortwave receiver unusable, completely blanketing recepting of all signals except the very strong ones.

The limiter shown will very effectively improve the signal-to-noise ratio so that even quite weak signals can be copied.

It is connected between the detector output and the audio input (if high impedance) or at some relatively high-impedance section between two audio stages — preferably the low level stages.

The diodes D1 and D2 can be any diode having relatively low forward resistance and very high back resistance. Type OA202 from Maplin is suitable. Resistors of ¼W (⅛W rating can be used if miniaturisation is desired).

The circuit is excellent for receivers having bandwidths down to 2 or 3 kHz. Increase the value of C1 for receivers having narrower bandwidths.

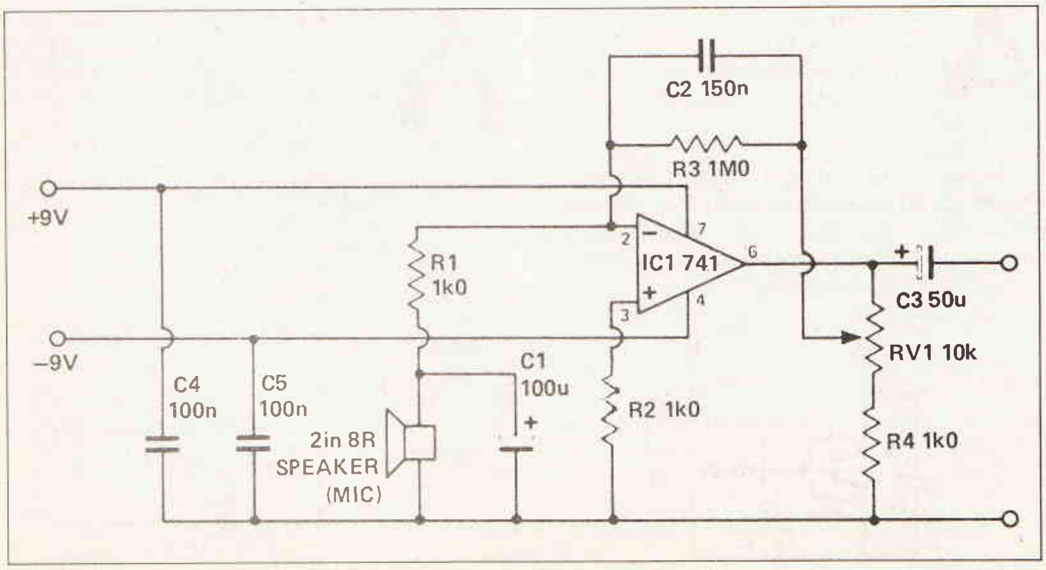


Heartbeat Preamplifier

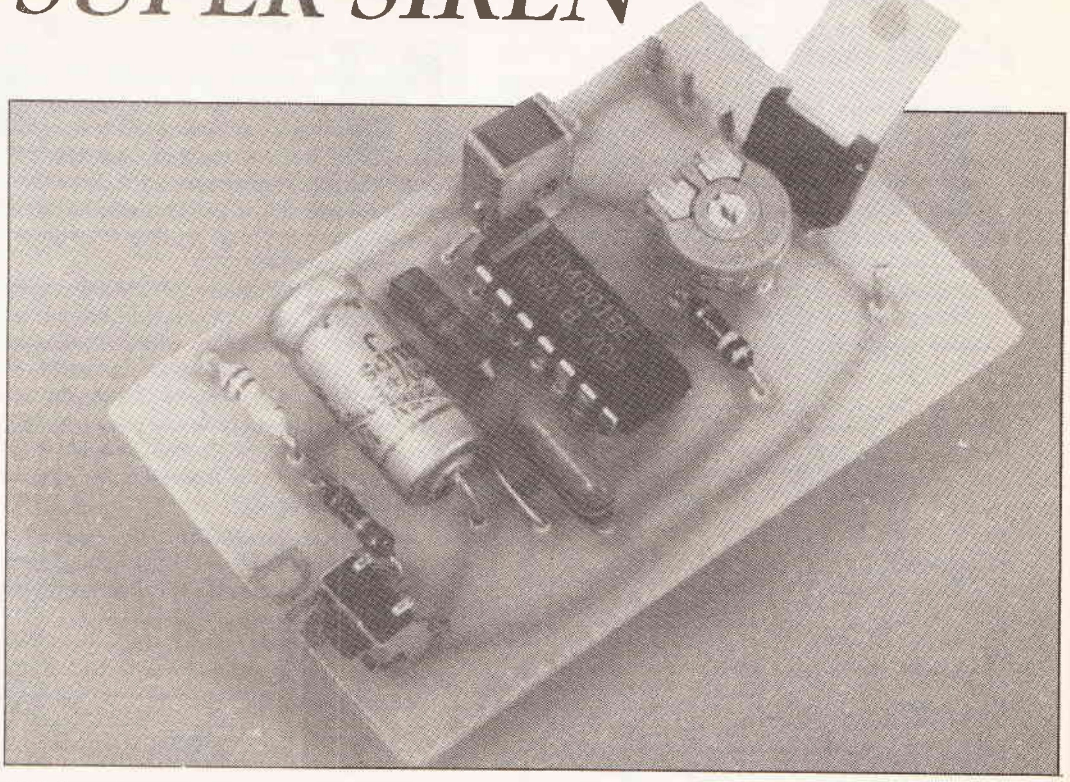
This simple circuit, when connected to an audio amplifier, allows one to listen to heartbeats. The low frequency gain is set by R1 and R3, in conjunction with RV1 and R4. RV1 permits the gain to be varied over the range 60-80 dB.

C1 and C2 introduce some low frequency cut, reducing 50Hz pickup whilst C4 and C5 help prevent instability caused by the high gain of the circuit.

The output should be connected to the magnetic cartridge input of the audio amplifier, with the bass turned up high.



SUPER SIREN



An incredibly loud sound, from an incredibly simple circuit. Keith Brindley explains.

It really doesn't matter what your alarm system is. It can be as simple as a push-button operated motor bike horn, to a remotely triggered burglar alarm (using, say, a commercially available passive infra-red detector). It could even be turned into a very effective door-bell — definitely guaranteed to nofity all in the household that someone is at the door. Whatever the alarm system, the sound output produced by this 1st Class project is pretty loud.

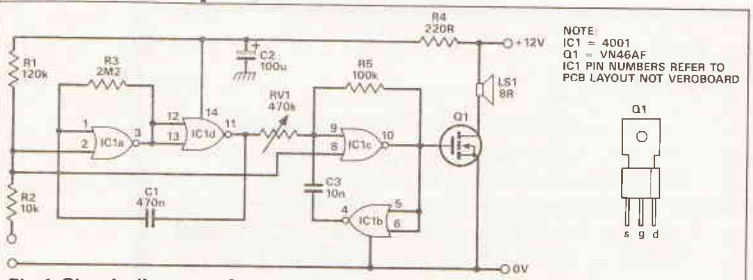


Fig.1 Circuit diagram of super siren.

PROJECT

Technically speaking, with a 12 volt power supply and connected to an 8 ohm loudspeaker, the circuit can theoretically deliver around 9 watts of sound power. And that produces a fairly piercing sound output from a good loudspeaker — sufficient, we hope, to scare away unwanted personnel from the vicinity (as well as the dog, guinea pig, and tortoise).

The project was initially designed with caravan security in mind — hence the requirement for a 12 volt power supply, as most caravans use an internal 12 volt lead-acid battery to power lights and water pump. The 12 volt power specification is by no means critical however, as the circuit will run satisfactorily with a power supply of as low as 6 volts (albeit with reduced sound power output), and as high as up to 15 volts (with a corresponding increase of sound power output). At a power supply of 6 volts, about 2 watts is generated. Upper voltage limit is set incidentally, by the maximum power which can be dissipated by the output transistor (Q1 in Fig. 1). This is 15 watts, corresponding to a power supply voltage of 15 volts.

The project is pretty versatile, and is not restricted to caravan use by any means. It can be used just about anywhere an alarm-type sound output is required.

Sound output is reminiscent of the emergency services, the nee-naa-nee-naa sirens, used by police cars and ambulances.

As detailed here, the siren operates merely by pressing a push-button switch. The project can be permanently connected to the power supply, as in its quiescent state the circuit uses only a few microamps of current. Pressing the push-button effectively switches on the circuit, driving the loudspeaker.

Mechanical push-button operation however, is not the only way the circuit may be triggered. A simple negative-going pulse at the input to resistor R2 will trigger the siren electronically for the duration of the pulse. Alternatively, a relay's contacts can be used to close the inputs electromechanically. Thus a number of methods allow the project to be interfaced with other circuits.

Before we detail methods and procedures of construction, a word about the loudspeaker. Any 8R loudspeaker can be used, provided that it has a power rating of at least that which the siren generates. And as described above, power output depends on power supply voltage. For your loudspeaker's sake, always err on the generous side and use a higher power rated loudspeaker than you calculate the project to produce. Generally speaking though, most hi-fi system loudspeakers should be OK, but check the loudspeaker's specification: preferably before you blow its cone, not after.

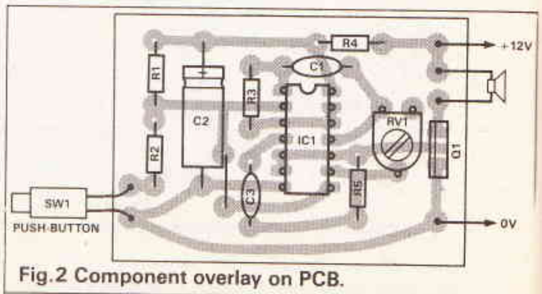


Fig.2 Component overlay on PCB.

Construction

Circuit of the ETI Super Siren is given in Fig. 1.

As usual in 1st Class projects, readers are offered a choice of construction on printed circuit board or stripboard. If you choose PCB construction, layout, overlay and wiring details are given in Fig. 2. Figure 3 on the other hand, gives details of stripboard layout, overlay and wiring.

Constructional details are pretty similar in either case. Start by inserting and soldering passive components first; resistors, followed by capacitors. Note that capacitor C2 is an electrolytic and needs to be polarized correctly.

At this point, insert and solder links; then PCB pins and integrated circuit socket if you choose to use them. PCB pins make it extremely easy to connect leads after the board is complete, while an IC socket eliminates the prospect of damaging the IC by heat when soldering into place. However, the IC in question, a CMOS 4001 quad two-input NOR gate device isn't expensive, so even if you opt to solder it in and subsequently cause damage, a new IC probably costs less than the socket in the first place!

Finally, insert and solder the semi-conductors, making sure they are polarized correctly. Needless to say, if you have soldered in an IC socket, the IC only needs to be pushed into place.

Setting Up

Procedure for setting up is straightforward. Initially, connect leads to the loudspeaker, power supply and a push-button switch, as shown in Figs. 2 & 3.

When you are sure all connections are correct, set preset resistor RV1 to about mid-position. Now, put in some earplugs and press the push-button. Even with ear-plugs you'll hear if the project is working. Preset RV1 is included in the circuit to allow different power supply voltages to be accommodated, although at any given voltage it can be adjusted to give optimum siren effect results.

HOW IT WORKS

Figure 4 shows the circuit of the ETI Super Siren in block diagram form. There are three main blocks.

A low frequency astable multivibrator is formed around gates IC1a & d. This has a frequency of around 2Hz, set by resistor R3 and capacitor C1. The astable is gated by the voltage on pin 2 of the integrated circuit. In quiescent mode this voltage is high, because pin 2 is connected to the positive power supply through resistor R1, and the astable is off (that is, not oscillating).

When the input of resistor R2 is taken to the negative power supply (say, if the push-button is pressed) the voltage on pin 2 is effectively taken low, which turns on the astable.

A voltage controlled astable multivibrator generating a frequency within the audio range (around 1kHz) is made up with the remaining gates of the integrated circuit (IC1b & c) together with frequency setting components resistor R5 and capacitor C3. This astable, like the previous, is gated by the input voltage. When the voltage at pin 8 is high the astable is off, when low the astable is on. Thus, when the push-button is pressed, both astables turn on simultaneously.

The frequency of the voltage controlled astable is adjusted by the voltage applied to pin 9 of the IC, derived from the output of the low frequency astable, via preset RV1. Thus, adjustment of preset RV1 allows slight adjustment of the frequencies generated by the voltage controlled astable. Further, as the low frequency astable output is a square wave voltage which merely switches between high and low states, the output frequencies of the voltage controlled astable are simple from one frequency to a lower one. Adjustment of preset RV1 therefore allows slight adjustment of the difference between the two frequencies generated.

Transistor Q1, a VMOS power FET, allows straightforward current amplification of the generated frequencies, increasing overall signal power sufficiently to drive the loudspeaker.

PARTS LIST

RESISTORS (all ¼ watt)	
R1	120k
R2	10K
R3	2M2
R4	220
R5	100k
RV1	470k miniature horizontal preset
CAPACITORS	
C1	470n polyester
C2	100 16V axial electrolytic
C3	10n polyester
SEMICONDUCTORS	
IC1	4001
Q1	VN46AF
MISCELLANEOUS	
PCB or stripboard	
PCB pins	
Push-button switch (if required – see text)	
IC socket (if required – see text)	
LS1 loudspeaker – 8R, power to suit supply voltage	

BUYLINES

All parts should be easy to obtain, either from your electronics hardware outlet or mail-order company. If you elect to build the project on printed board, you'll find the board in this month's ETI PCB Service.

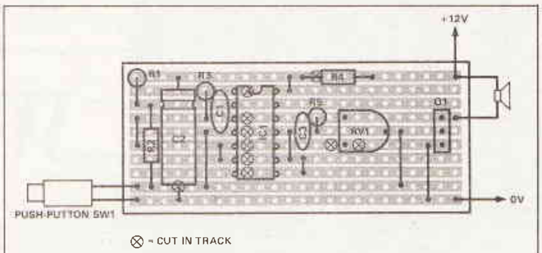
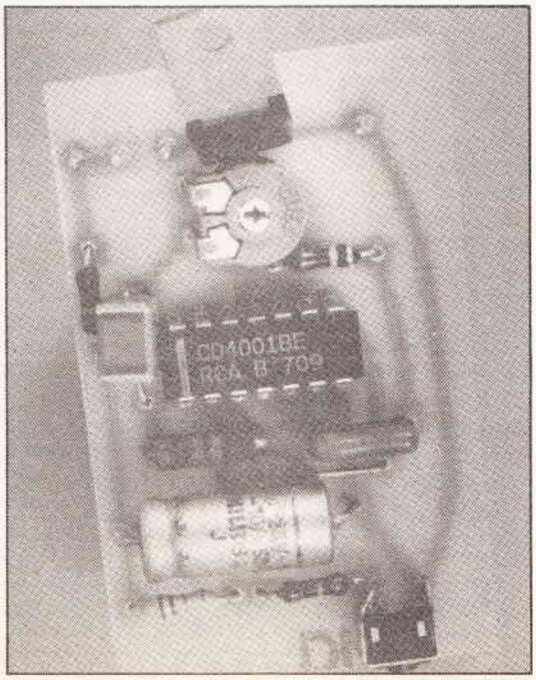


Fig.3 Component overlay on stripboard.

Fig.4 Block diagram of the circuit.



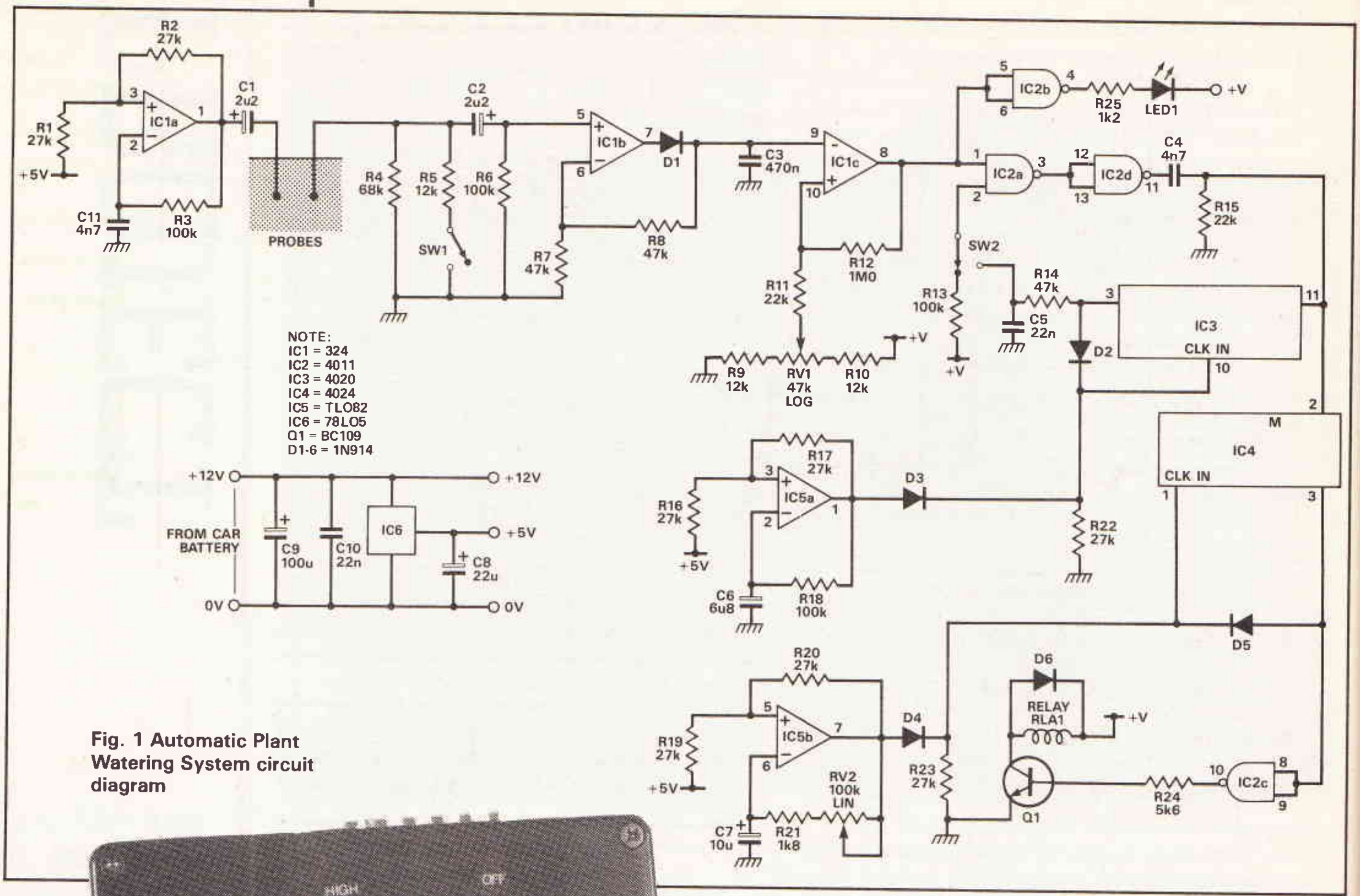
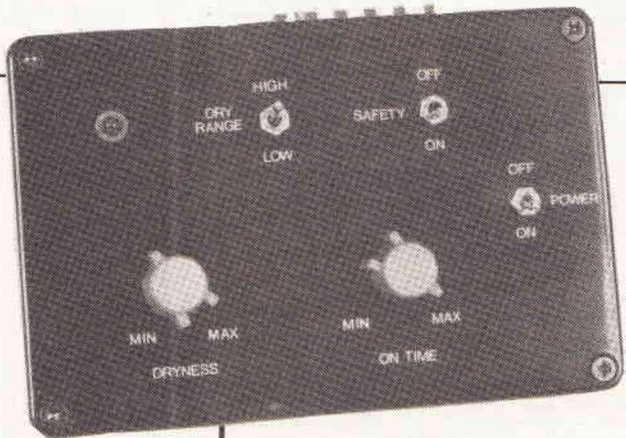


Fig. 1 Automatic Plant Watering System circuit diagram



PROJECT

WATER HOLE

Water project. Water relief. Water we doing? Edward Barrow explains all

Going on holiday can be a problem — especially for your plants. Do you entrust their fate with your neighbours, or do you leave your precious seedlings to the whims of nature? One solution is the ETI Automatic Plant Watering System, which pumps water from a reservoir whenever they need watering. Given that the reservoir is large enough, you can now leave your plants in the knowledge that they'll be OK.

The project uses a simple probe, inserted in the soil, to detect resistance change; operating on the principle that if the resistance of the soil increases its water content is decreasing. At a predetermined level of resistance (chosen by you), the system operates the water pump to force water onto the soil.

A variable preset time allows different soil types and plant requirements to be catered for, while an in-built safety feature prevents over-watering.

Construction

Circuit of the Automatic Plant Watering System is shown in Fig. 1. Component overlay and wiring details are shown in the PCB layout of Fig. 2.

The usual rules apply to construction. First, mount and solder in all passive components: resistors, capacitors and presets. Next mount and solder semiconductors, starting and diodes, followed by transistors, regulators, and ICs. Finally, mount and solder the relay and all interconnecting leads.

Testing

First connect the circuit up to a 12V power supply. Check that opamp IC1a is oscillating at around 1000Hz, by connecting a pair of headphones via a 1k0 resistor between pin 1 of IC1 and ground. A high pitch squeal tells you all is well here.

To test the remaining parts of the circuit, set potentiometer RV1 to about mid-way and over-ride the safety feature with switch SW2. By touching the probe terminals together the equivalent of very wet soil is achieved — this should turn off LED1. Then by removing the short from the probe terminals dry soil should be simulated. This will illuminate the LED and the relay should turn on for the set on-time period. This can either be heard by the clicking of the relay contacts or measured by using a meter set to resistance on the contacts.

It takes a bit of patience to test the project's safety feature, as it has an on-time period of some two hours. One way around a boring wait is to use the relay to switch on some audible alarm, while you retire to the other end of the room to watch telly. When the safety feature operates; you'll hear it!

Setting Up

Choosing a probe can be a problem and it's best to go for a sturdy option such as a quarter-inch mono jack plug. The prototype uses two 16 inch barbeque

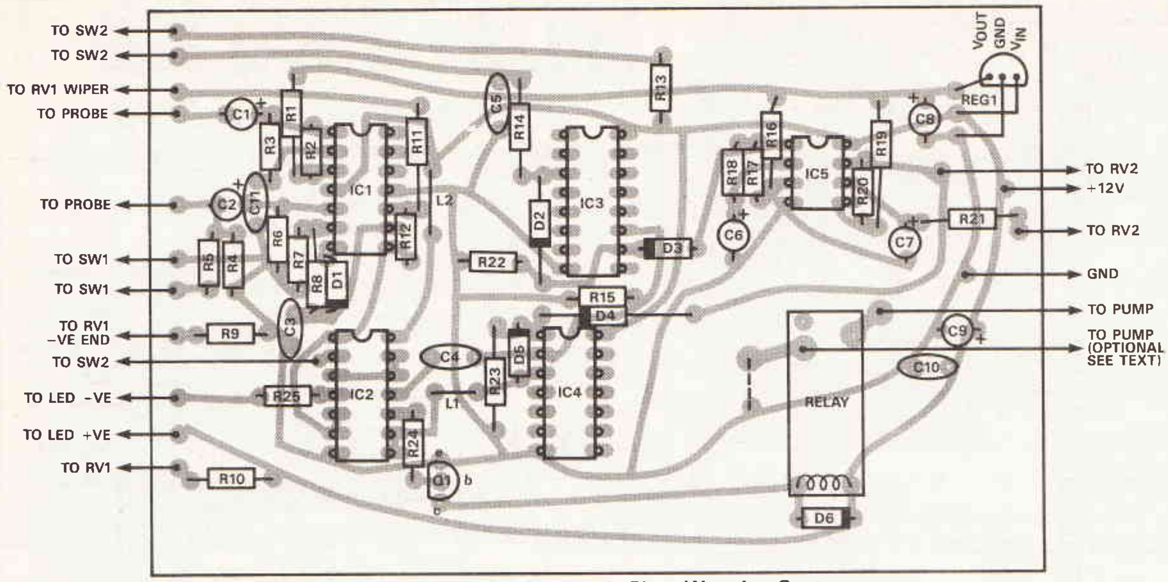


Fig. 2 Component overlay and wiring details of the Automatic Plant Watering System

skewers placed about 6 inches apart in the soil. These are probably somewhat unwieldy, however, for general use and a jack plug or similar probe is preferred. Whatever you use, care should be taken in positioning: don't place it too close or far away from the water source, allowing a good average reading and preventing triggering too often.

To calibrate the dryness threshold, wait until you have a good example of the soil at the dryest point you want it, then adjust potentiometer RV1 until LED1 is just illuminated. To do this you may have to switch range using switch SW1.

Next thing is to set the on-time. This is done by over-riding the safety feature with switch SW2 and momentarily shorting the probes (simulating the soil being wet, then drying out). This saves a long wait for the soil to dry out again before you can have another bash at adjustment. Adjust potentiometer RV2 until the on-time is sufficient for your needs. This, of course, depends on the size and number of plant-pots and the type of pump used.

An old recharged car battery can be used to power the project. This has the advantage that if a car cooling or windscreen wiper pump is used to pump the water this, too, can be similarly powered. These types of pumps are ideal for small greenhouses.

HOW IT WORKS

An overall block diagram of the Automatic Plant Watering System is shown in Fig. 3.

As soil dries out and its water content falls, then its resistance increases. The simplest way to measure soil resistance is to use the soil as part of a voltage divider (see Fig. 4). This is fine for spot measurements but for long term applications it leads to electrolysis of the chemicals in the soil and electrolytic destruction of the probes. Also, if the probes are metallically dissimilar they form a battery with the chemicals in the soil which, in high impedance environments, will lead to errors.

The way around this is to use an AC signal and to decouple input and output probes. This eliminates electroysis effects and any bias voltages formed (see Fig. 5).

The returned AC signal is rectified, so the resulting voltage is inversely proportional to the resistance of the soil and is applied to a comparator. When the voltage falls below a preset level (that is, the soil has reached the maximum level of dryness you want), the comparator output is forced high. A LED displays the state of the comparator's output, this helps us in setting the level of dryness.

If the safety feature is switched off, then when the comparator is turned on, the divide-by-128 counter is reset and turns on the relay for 64 clock cycles. This clock frequency is made variable so the on-time can be controlled.

A second counter is used to prevent the divide-by-128 counter turning on the relay more than once every two hours or so. This is a safety feature which prevents plants being over-watered. In operation, a fixed frequency oscillator clocks a divide-by-8192 counter which, while it is counting, disables the divide-by-128 counter.

Opamp IC1a is configured as a relaxation oscillator whose output is used as the test signal for application to the probe. After being capacitively coupled it is attenuated by the combination of its own output resistance and resistor R4 or R5 (depending on the range selected). Note that if, for some reason, the range covered is not sufficient, then the values of either R4 or R5 can be altered to suit.

An active rectifier with a gain of 2 is formed around opamp IC1b. Its output feeds the comparator IC1c. If the generated voltage is greater than that set by potentiometer RV1, the comparator output will be high. A small amount of feedback is used to ensure clean switching and good noise immunity.

Result of this action depends on the state of the counter IC3. If the circuit has not been triggered in the previous two hours then pin 3 is high. If the comparator now goes high both counters IC3 and IC4 are reset, via gates IC2a and d. This drives pin 3 low on IC4, thus turning on transistor Q1, until after 64 clock cycles pin 3 goes high, stopping the clock and also turning off the transistor.

Similarly when IC3 is reset, pin 3 goes low for the next 4096 clock cycles. This prevents the comparator from resetting IC4 for around two hours. This safety feature can be over-ridden by switch SW2, when the comparator has a free hand to reset IC3.

Both clocks are generated by relaxation oscillators formed by IC5a and b. The first is fixed at a frequency about 0.5Hz and feeds IC3. If this frequency is inadequate, it can be changed by altering either resistor R18 or capacitor C6. Frequency can be calculated by the formula, $f_{out} = 1/(2.2 \times R18 \times C6)$. This frequency sets the repetition time at $4096/f_{out}$ seconds, which is, for the component values used, around two hours.

The second clock built around IC5b feeds IC4 and its frequency can be varied by potentiometer RV2, from about 0.5Hz to 20Hz. This gives an on-time range of about 3 seconds to 2.5 minutes. Similarly, if inadequate, this can be adjusted by altering components R21 or C7, according to the formula, on-time (max) = $64/f_{out2}$ (max), where f_{out2} (max) = $1/(220000 \times C7)$.

Both clocks are gated, using diodes D2, D3 and D4, D5 as simple OR-gates with outputs IC3 pin 3 and IC4 pin 3, respectively. Resultant waveforms are shown in Fig. 6.

Gate IC2c buffers the output pin 3 of IC4 and inverts it, driving the transistor Q1, which is configured as a simple switch operating the relay.

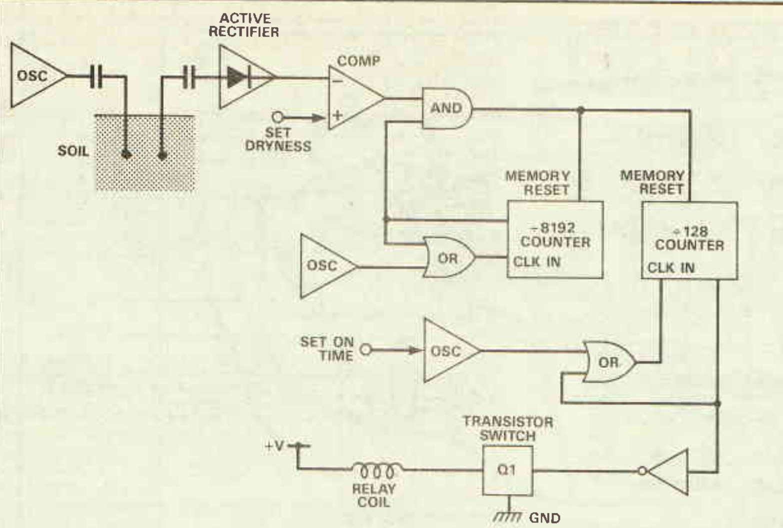


Fig. 3 Block diagram of the Automatic Plant Watering System

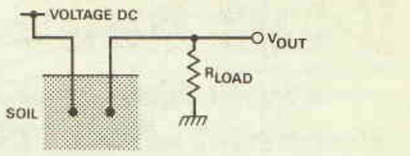


Fig. 4 Simple voltage divider, using the soil's resistance

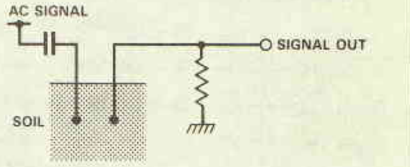


Fig. 5 AC voltage divider to eliminate electrolysis effects

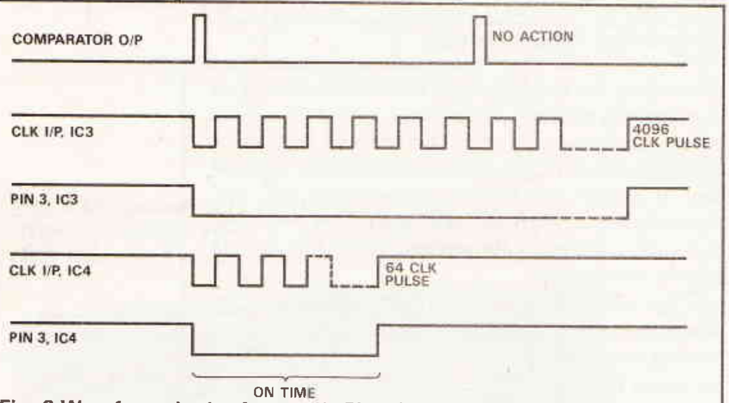


Fig. 6 Waveforms in the Automatic Plant Watering System circuit

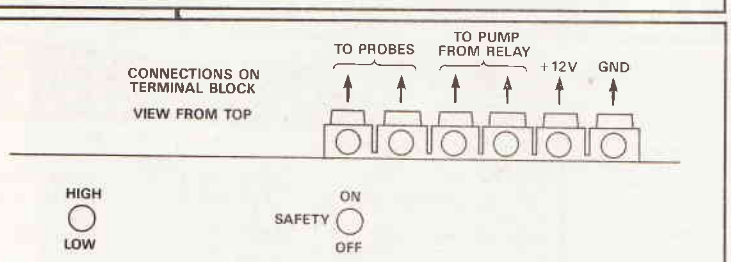
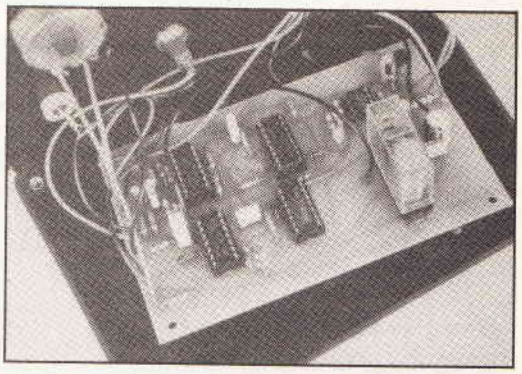


Fig. 7 Terminal block connections on the prototype

Alternatively, if your greenhouse features mains power, or if the system is to be used indoors, a mains pump will be preferred and a more conventional 12V power supply can be used for the project.

The irrigation set-up is left to the readers' ingenuity, but an overhead sprinkler type of system is probably best, as it gives an even spread of water over a large area. An alternative is to use one main pump, coupled to many probe circuits; each controlling water valves for a different plant or section of the greenhouse.



PARTS LIST

RESISTORS (all ¼W)

R1,2,16,17,19,20,22,23	27k
R3,6,13,18	100k
R4	68k
R5,9,10	12k
R7,8,14	47k
R11,15	22k
R12	1M
R21	1k8
R24	5k6
R25	1k2
RV1	47k log
RV2	100k lin

CAPACITORS

C1,2	2µ2, 16V tantalum
C3	470n polyester
C4,11	4n7 polyester
C5,10	22n polyester
C6	6µ8, 16V tantalum
C7	10µ, 16V tantalum
C8	22µ, 16V electrolytic
C9	100µ, 16V electrolytic

SEMICONDUCTORS

IC1	LM324
IC2	4011
IC3	4020
IC4	4024
IC5	TL082
IC6	78L05
Q1	BC109
LED1	red LED
D1, 2, 3, 4, 5, 6	1N914

MISCELLANEOUS

SW1	SPST toggle
SW2	SPDT toggle
RLA1	16A, 12V DC relay
PCB, case to suit	

BUYLINES

All parts for this project are widely available. The relay is from Rapid Electronics and is of a widely compatible format. A suitable low-voltage pump can be purchased from a car scrap yard or a car component dealer.

WHY DON'T THEY . . . ?

Geoff Martin tries to unlock some of the frustrations in life

Why doesn't somebody invent a pushbutton telephone with your own personal security code so you can be the only one to make a call? It beats me why such a simple idea has not been adopted as a standard option for the modern telephone. It would certainly overcome a lot of problems in industry and in the family household. It's at home where tempers could reach the limit particularly at the crucial three months point when the phone bill comes in, and all because young Darrin and Katy have had so much fun chatting long distance to their mates all night.

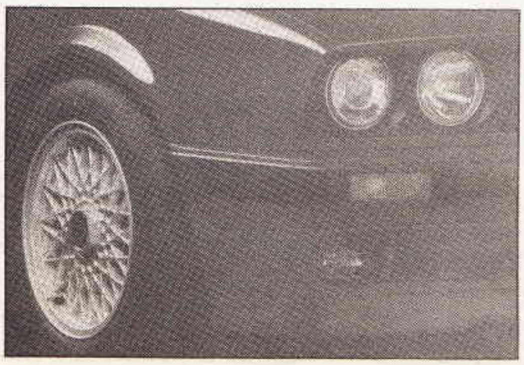
The right combination

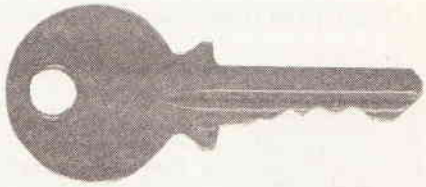
The operation couldn't be simpler, pick up the handset, key in your PIN number and *hey presto* you've accessed the dialling tone ready to make a call. Also with some extra thought, if someone happens to be looking over your shoulder at the time, it could be a simple matter of re-programming the chip with a different code. This would have solved the problem of those parents achieving near heart failure when receiving £1000 telephone bills as a result of 'somebody' having a party on the phone using the premium rate chatlines. Perhaps the reason for this non invention is more deep rooted and that marketing such a product could lead to a loss in revenue for the telephone companies.

Why do we continually have to run down the car battery after having driven around in bad light conditions and then forget to switch off the lights when leaving the car? All it needs is an audible warning when the ignition key is removed. An alternative is to connect the lights up to the ignition key so they only operate when the key is in place.

While still on the subject of transport, it's amazing how many cars can still be locked with the keys inside. The panic and incredible waste of time in breaking in to the wretched thing particularly abroad could all be avoided if all new cars adopted a fail safe system.

You want to be able to lock yourself in the car in the event of an emergency by pushing a mechanical button down or perhaps by electro-mechanical means with the flick of a switch on the dashboard. What you don't want to happen is for the door to slam and lock with you on the outside and your keys on the inside. And before you all say the technology is here to lock your car remotely by infra-red beam, just remember the battery can run down that operates the system. So there is need to carry the key to cover all eventualities after all!





The key to the problem

It's funny how domestic door locks have never really changed over the years. I speak of the metal key and latch variety. It's a system that admittedly is simple and reliable but technology can and has given us more sophisticated locks. The more familiar ones that come to mind are the combination electro-mechanical types and more recently the magnetic strip card. I have been impressed with the latter in a foreign hotel to lock or unlock the hotel room door. You are issued with what looks like a credit card made on a bad day. It is made of thin plastic with the now familiar magnetic stripe along its back. The only thing required on your part is to zap it through the slot on the door and you are in and I don't mean using it to ease open the door by the standard burgler method of slipping it past the latch either. My experience of this particular card did not end there. The flat 'key' was essential to switch on the rooms electric power by placing it in a little slot on the wall inside.

So if you have to leave the building, you take your key and out go the lights. Full marks to the designers for this energy saving device. It has to be said though, these 'high tech keys' can be left in the room whilst the occupant slams the door behind them. Where this is a minor annoyance in a hotel it could be more upsetting having to break into your own home.

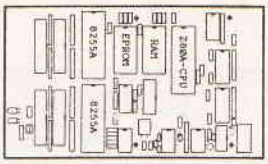
Dark Ages

Why can't the amateur unlock the secrets of the latest constructional technology in magazines such as ETI? Have you seen many projects exclaiming that you too can build your own CD player, video recorder, personal organiser, digital mixing desk or magnetic card door lock? I think not. You may see features outlining the theory of these wizard machines but certainly not projects. Why is this?

We've seen the industry race ahead leaving state-of-the-art electronics in the hands of the very few. The poor old amateur has been left in the dark ages to make the best he or she can do with the bewildering array of chips and discrete components available.

But take heart, very often the simplest ideas are the most effective. So come on all you constructors, let's publish all those ingenious but effective projects and banish some of the minor annoyances in life.

Interak 1



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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 too!

Although no serial interface is included, it is easy for a Z80A to waggle one bit up or down at the appropriate rate — the cost is a few pence worth of code in the program: why buy hardware when software will do?

Applications already identified include: Magnetic Card reader, mini printer interface, printer buffer, push button keypad, LCD alphanumeric panel interface, 40-zone security system, modem interface for auto sending of security alarms, code converter (eg IBM PC keyboard codes to regular ASCII), real time clock (with plug in module), automatic horticultural irrigation controller.

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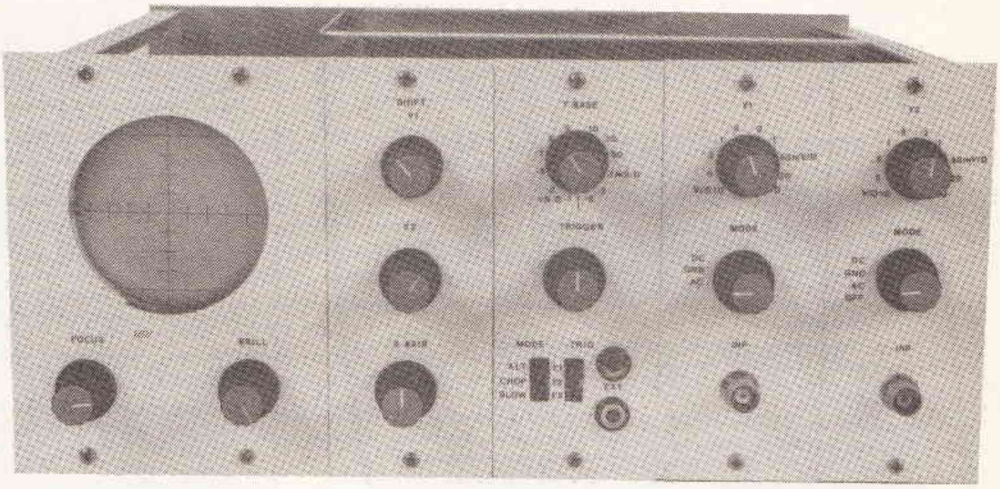


PART 2: More construction and testing

Dennis Stanfield concludes his article on this very economical 'scope

Last month saw the completion of the motherboard, driver board, timebase and power supply. We now turn our attention to amplifying the input signals. This is accomplished with two distinctly separate amplifiers — the Y1 input amplifier (circuit shown in Fig. 13) and the Y2 input amplifier (Fig. 14).

The Input Boards

The Y1 and Y2 boards are virtually identical with the exceptions that the beam switching and single/dual trace mode switching takes place on the Y2 board. Component overlay for the Y1 PCB is shown in Fig. 15 together with connection details. Similary Fig. 16 shows the same for the Y2 PCB.

Construction

The input attenuator is constructed on two 30mm square pieces of PCB drilled and mounted on the main board as shown in Fig. 17, R403-5 and C402-4 being soldered between the tags of switch SW402a and the rearmost support panel. The entire switch panel may be built up in one piece and then added to the main board, the wiring of the switch wafers is as shown in Fig. 18. It should be noted that make before break wafers are necessary for SW402a and SW502a to avoid placing the full input voltage onto R406,7 and Q401 as the switch wiper moves between contacts.

A dual FET has not been used in the input stage due to the high cost of such devices and the difficulty in finding a suitable source of supply. If available a device such as an E421 or E430 may be substituted directly for Q401,2 without further modification. A dual FET will give improved thermal tracking and better baseline stability when switching between ranges. (The baseline shift is due to the differing 733 gains operating on the tiny differential voltages set up by Q401 and 402.) Thermal equalisation of the existing pair of transistors can be improved by placing their casings in intimate contact — stick them together with a tiny spot of superglue!

It is most important that all work should be neat and all component leads kept as short as possible.

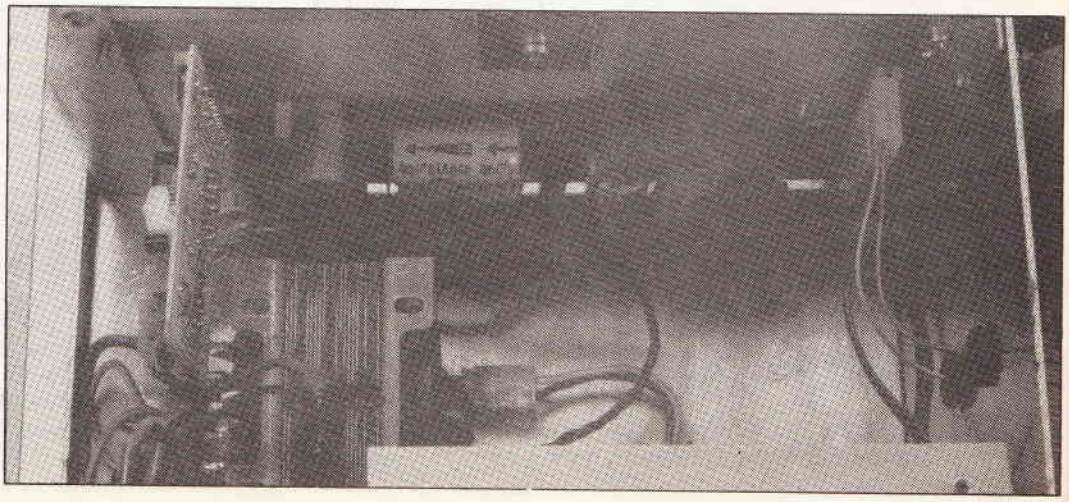
The BNC input socket is mounted through the fascia and screening panels and connected to the Y1 board by the leads of R401.

Setting Up

Due to the layout of the on board components it is not possible to adjust the trimmer capacitors and preset resistors on the Y1 board with the Y2 board also in place. Therefore a small set-up board as shown in Fig. 19 is built up on stripboard and plugged in to the Y2 slot. This set-up board routes the Y1 signal through to the Y deflection amplifier and holds IC201 in the Y1 mode. The 56R resistors on the set-up board load the 733 outputs and prevent any parasitics.

Firstly RV401 should be adjusted to give minimum change in trace position when switching SW402 through its various ranges. Make this adjustment with no input signal and SW401 referenced to ground.

With SW401 switched to AC and the timebase set to a (at this stage) nominal 1μs per division input, apply a good quality square wave of 2-3V peak to



PROJECT

HOW IT WORKS

The Input Amplifiers

These use a fairly familiar circuit designed around a video amplifier IC.

The input attenuator is either AC or DC coupled to the input by SW401 and the various sensitivity ranges are achieved by a combination of varying the division factor of the input network and the gain factor of the 733 amplifier. The network around R406,7 gives some measure of protection to Q401 against all but the most gross overloads. It is however better not to depend on this as FETs are delicate devices by comparison with the valves which would have been used in this position in the past. Q401 is configured as a source follower providing the necessary high input impedance to avoid loading the attenuator. IC401 is a high speed wideband video amplifier with a full power bandwidth extending to over 35MHz which, due to its very high common mode rejection ratio even at very high frequency, is capable of providing a balanced output from a single ended input. The emitter follower Q403 provides a buffered output to the trigger amplifier.

The power supply lines to the input amplifier are heavily decoupled by R419,20 and C406,7,8,9.

IC502 on the Y2 board is driven by antiphase square waves from the switch generator module to select either Y1 or Y2 output to the deflection amplifer.

The beam switch generator

This has three modes of operation controlled by switches on the timebase and Y2 boards.

1. Single trace mode — with no input from SW501b, R607 holds the input to IC601a high so disabling the oscillator IC601b,c. R607 is also connected to the set input of IC602 and holds output Q — the Y1 select enable line high and the Y2 select line low.

2. When the Y2 amplifier is switched on SW501b pulls the inputs to IC601a and IC602 'set' low. What happens next depends on the state of the timebase alt/chop switch SW302b.

3. If SW302b is set to display alternate sweeps then R606 holds one input to IC601c low so that the oscillator remains disabled and the output of IC601c is held high so allowing IC601d to pass the 'Alt gate' signal through to IC602 whose outputs change state on each pulse.

4. If SW302b is set to chop or slow mode then the junction of R606 and IC601c is pulled high and the oscillator is enabled. Running at a frequency of about 100kHz the output of the oscillator is gated through IC601d by the 'Alt gate' signal which is high for 99% of the time (at the ramp rates at which chopped mode is likely to be used).

The circuitry around Q601,2 performs signal level shifting from a 0V ground reference to a −12V ground reference. Diodes D601,2,3 compensate for the fact that a TTL high level is a long way short of 5V. Without these Q601 would never switch off and R604 would probably not last long.

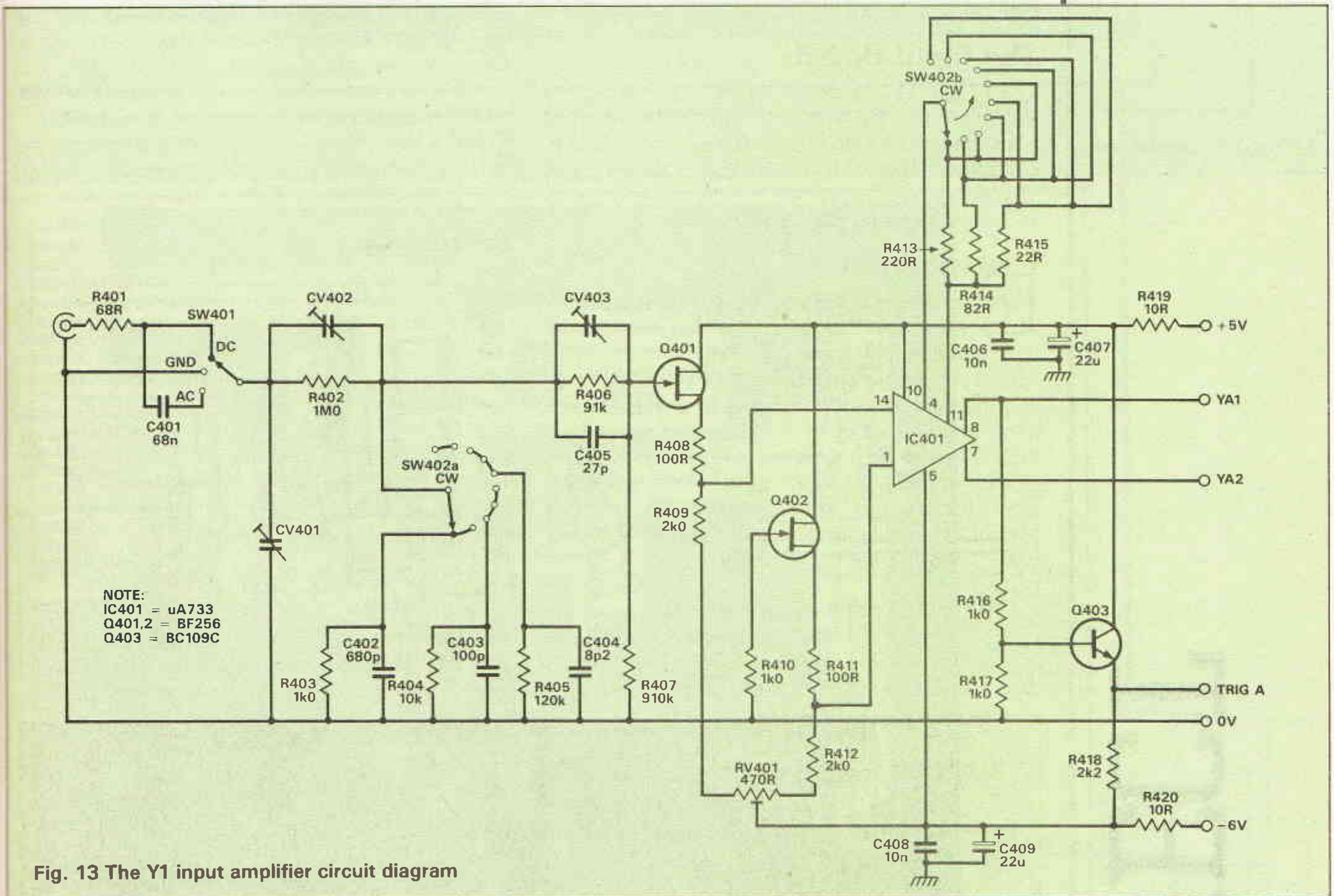


Fig. 13 The Y1 input amplifier circuit diagram

peak (from, say, a TTL oscillator) at about 1MHz into the BNC input socket. You should feed the input via a properly terminated probe if possible as lengths of wire may cause parasitic oscillations.

Set CV403 to mid travel and adjust CV401 for best waveform and CV402 for correct signal deflection height. CV403 and CV201 may then be adjusted for the best shape to the fast edges with minimum overshoot or ringing if possible a square wave of around 5-6MHz can then be applied and any further tuning carried out.

The Y2 amplifier is identical to the Y1 construction details given above but with the additional note to take due care in the handling of IC502 which is a CMOS device.

Switch Generator Construction

This is a simple board and no comment is necessary beyond noting the usual precautions in handling IC601 and IC602.

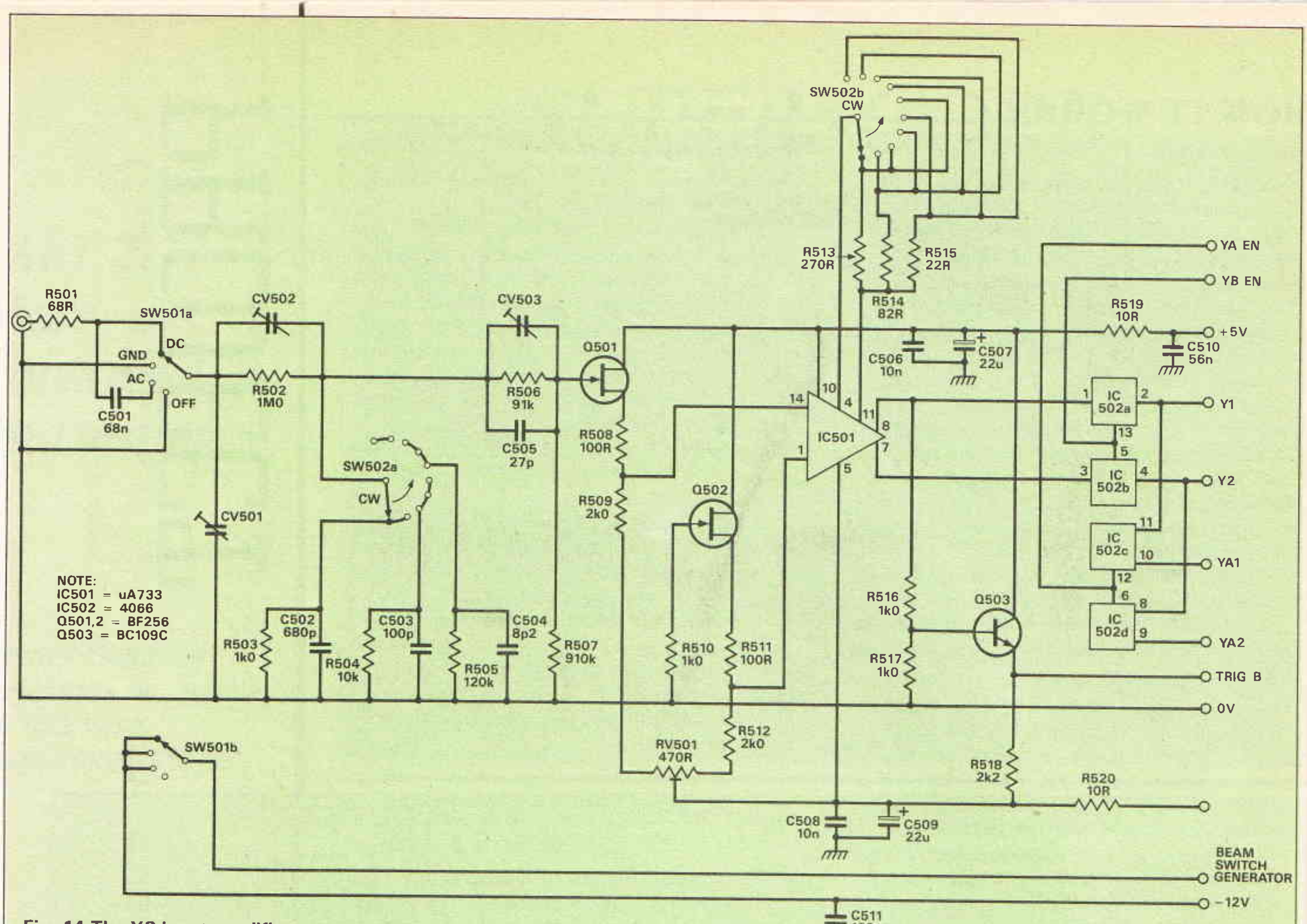


Fig. 14 The Y2 input amplifier

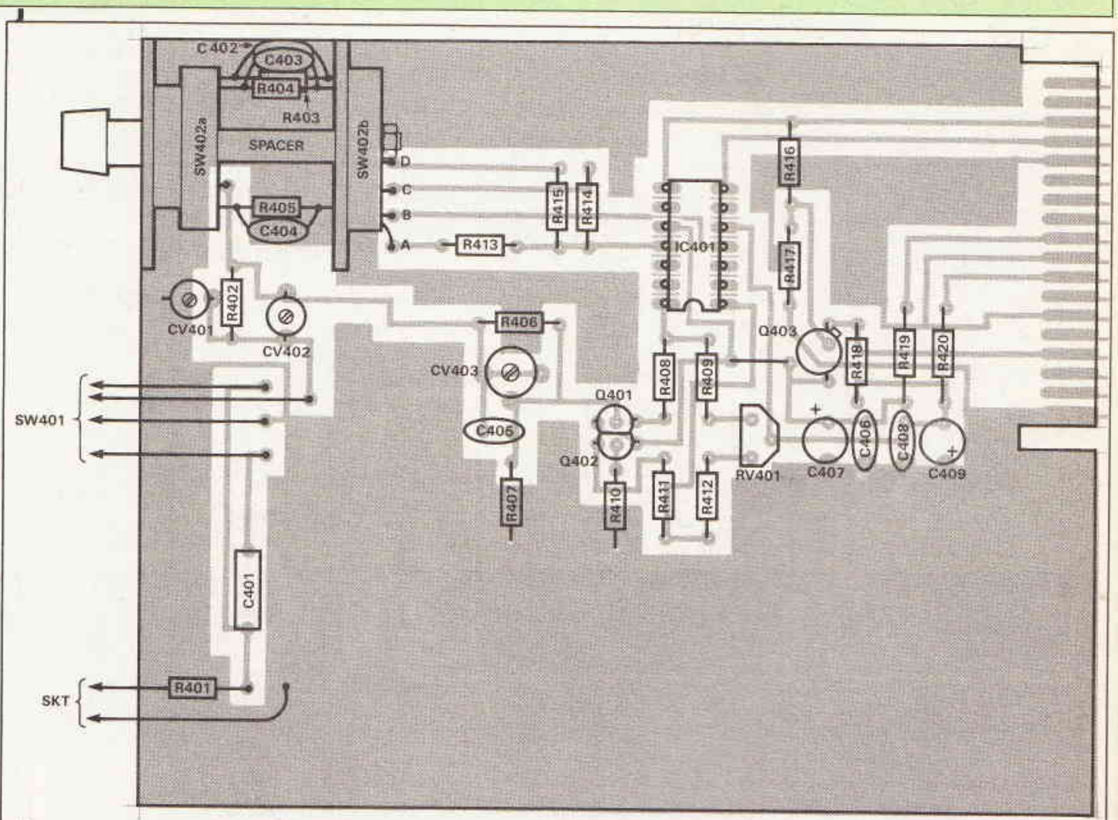


Fig. 15 Component overlay for the Y1 amplifier

Setting Up Y2

Remove the Y1 set-up board from slot 4 and plug in the Y2 and switch generator boards. Setting up is as for Y1 and the two channels should be driven for comparison. It should be noted that in some circumstances driving both channels from a single source may result in some interaction between them with consequent degradation in the signal waveform.

The Timebase

It is assumed that a second scope is not available to

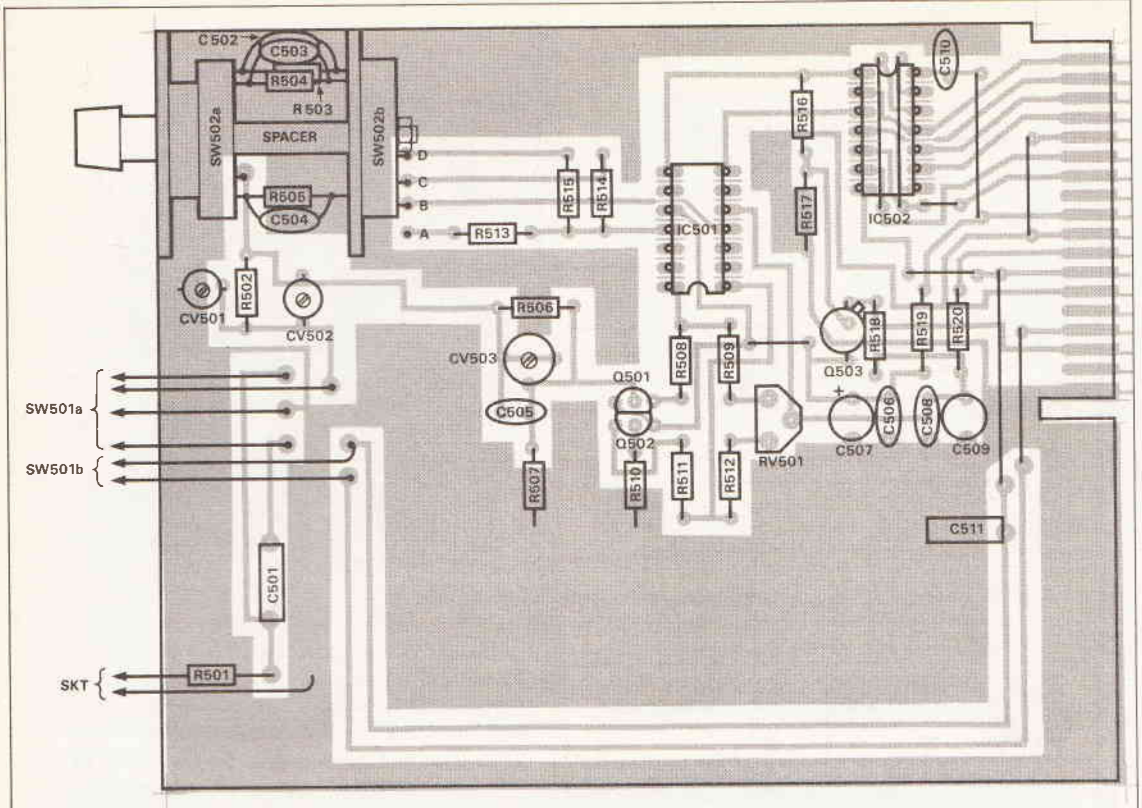


Fig. 16 Component overlay for the Y2 amplifier

display the ramp waveform — why else would you be building this one?

A known frequency reference is however necessary and a crystal controlled TTL oscillator cobbled together from bits out of the spares box would do very well.

Set the timebase to a suitable (nominal) rate and input the signal to either Y amp. Set trigger selector switch and adjust RV301 for correct triggering. Adjust RV302 to give the correct number of divisions per cycle. For example with a 1MHz signal reference set the timebase to 0.5µs per division and adjust RV302 so that each cycle is exactly two divisions in length. If necessary RV303 which adjusts the peak to peak height of the ramp and RV204 which adjusts the X axis gain may be trimmed to achieve calibration. It should be noted that at some settings RV303 can affect the proper action of the beam switching 'Alt gate' output in the fastest timebase ranges. This single adjustment sets up all the timebase primary ranges.

Switch SW301 to the 0.5ms per division range, switch SW302 to its x10 slow position and input a 50Hz signal to one of the Y amps. One cycle of the 50Hz signal should be four divisions in length. If not the value of the tantalum and polyester padder capacitors C305a-c may be changed as necessary to achieve an accurate ramp period. Reducing the total capacitance increases ramp speed and vice versa.

Display

Input a sine wave, the frequency is immaterial, and adjust the brilliance and focus controls for the best display noting that it is not considered good practice to simply go to maximum brightness as sharp focus is then more difficult to achieve. With an **insulated screwdriver** then adjust the astigmatism control RV101 to peak the focus. The focus and astigmatism controls interact and some repeated tweaking of each may be necessary.

Case Construction

The form of construction depends very much on the constructor. The prototype is housed in a home made casing of 2mm aluminium, the parts of which were supplied and cut to size by a local engineering works for about a tenner. The internal framing is cut from 12mm aluminium angle extrusion available from the larger DIY outlets. For those who feel capable of a bit

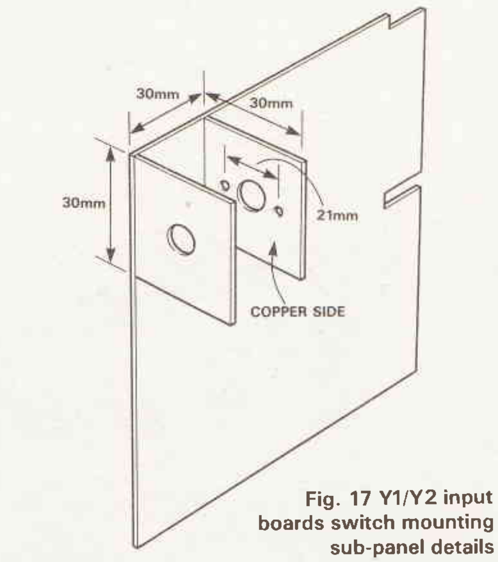


Fig. 17 Y1/Y2 input boards switch mounting sub-panel details

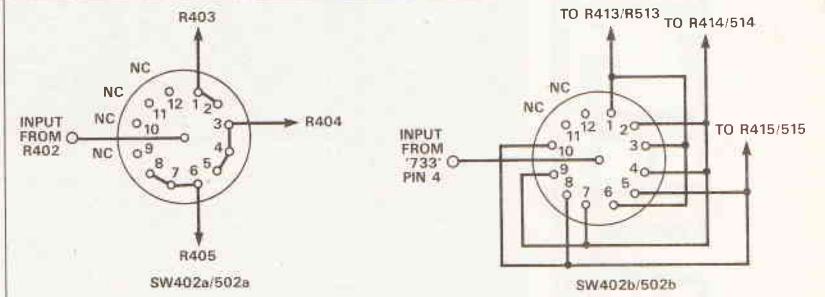


Fig. 18 Switch 402 wiring

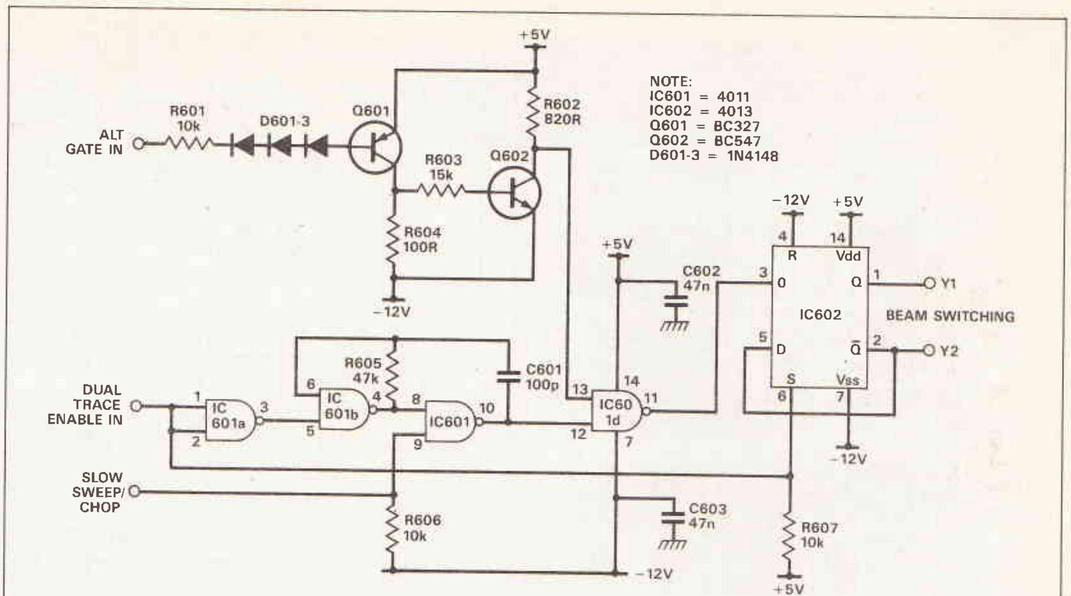


Fig. 20 Beam switching generator circuit diagram

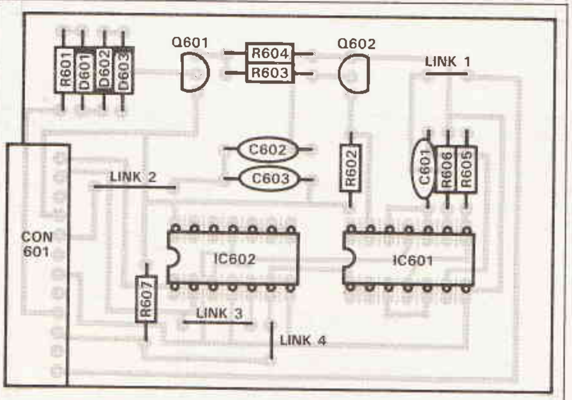
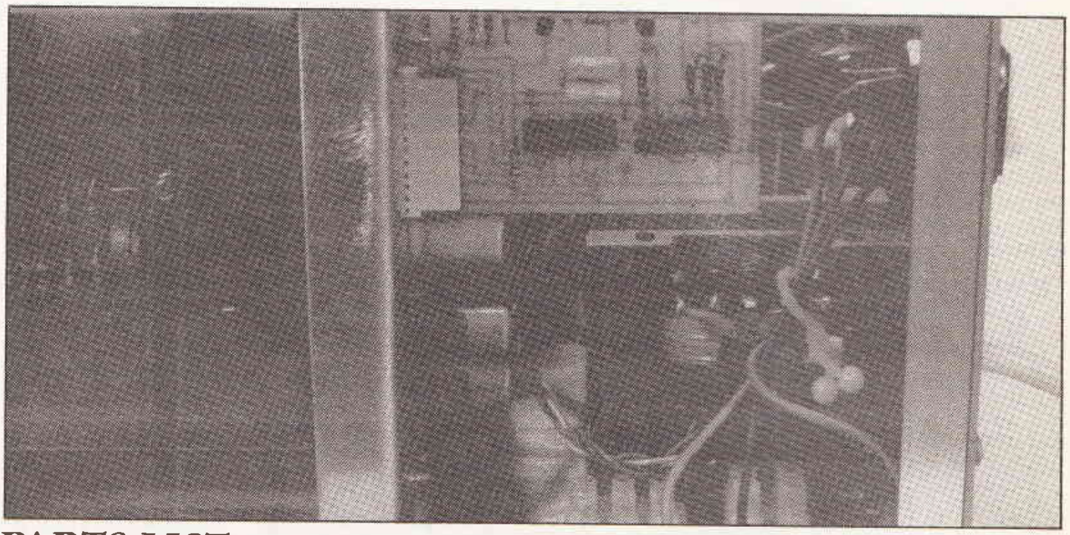


Fig. 21 Beam switch generator board — overlay

of panel bashing, a similar case may be made. For those who would prefer to use a ready-made case it should be of 12″ × 10″ × 5½″ at least (for a VCR tube) and the front panel dimensions shown should be used. The internal wiring layout is shown in Fig. 8.

The graticule presented some difficulties. Prototype solution is a graticule drawn on plain white paper using a very fine ink drawing pen and photocopied onto a clear acetate sheet. *(A possible alternative might be to use a thin acrylic sheet and scoring on lines with a marking knife. These could then either be illuminated from the side of the sheet or filled with a black marking paste — Ed)*

As the tube EHT is determined by the transformer winding, the constructor might consider the more modern tube alternatives available at reasonable increased costs.



PARTS LIST

Beam switch module

RESISTORS

R601,6,7	10k
R602	820R
R603	15k
R604	100R
R605	47k

CAPACITORS

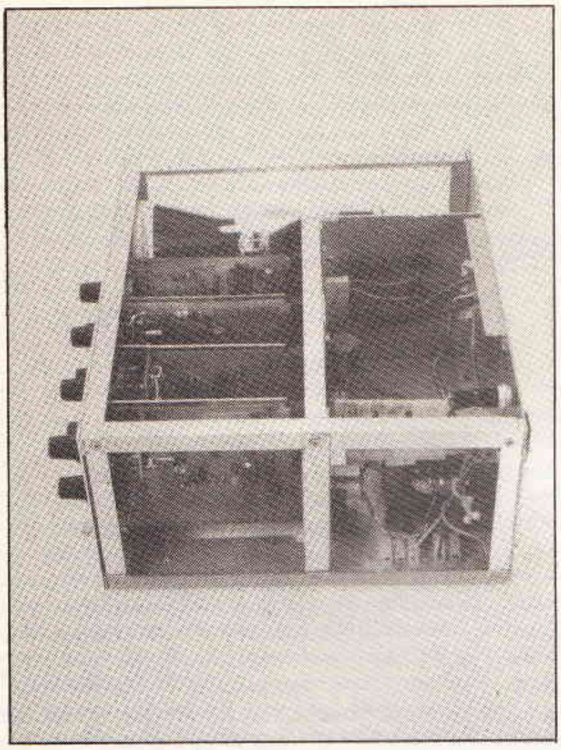
C601	100p, ceramic
C602,3	47n, polyester

SEMICONDUCTORS

Q601	BC327
Q602	BC547
IC601	4011
IC602	4013
D601,2,3	1N4148

MISCELLANEOUS

SKT601	Rt angled 12w 0.1″ connector (Maplin ref. YW30H)



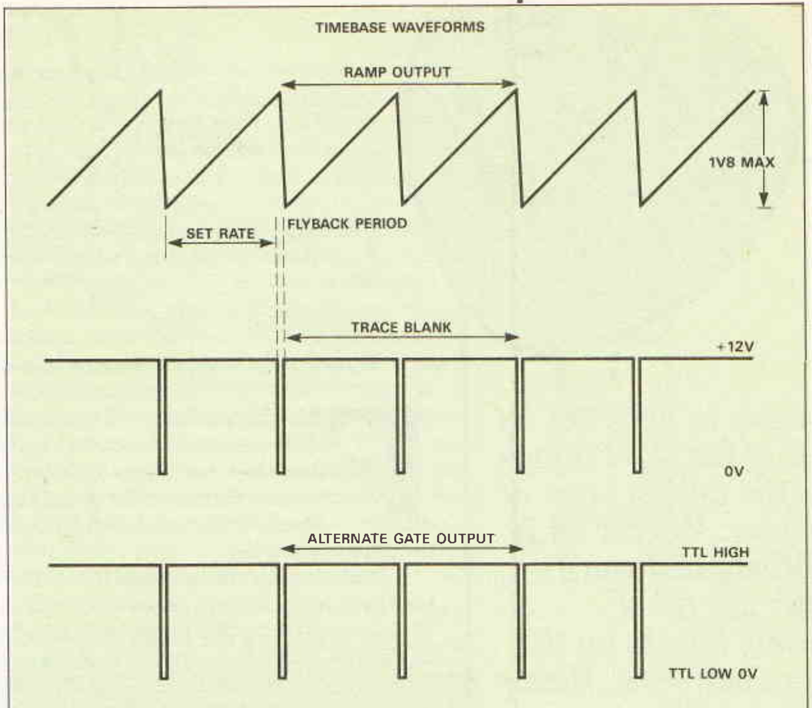


Fig. 22 Timebase waveforms

PARTS LIST

Y1 board

RESISTORS (all ¼W 5% unless stated)

R401	68R
R402	1M, 1%
R403,10,16,17	1k,1%
R404	10k, 1%
R405	120k,1%
R406	91k, 1%
R407	910k, 1%
R408,11	100R, 1%
R409,12	2k, 1%
R413	270R, 1%
R414	82R, 1%
R415	22R, 1%
R416,17	1k
R418	2k2
R419,20	10R
RV401	470R preset

CAPACITORS

C401	68n, polyester
C402	680p, ceramic
C403	100p, ceramic
C404	8p2, ceramic
C405	27p, ceramic
C406,8	10n, ceramic
C407,9	22µ tantalum
CV401,2	12p trimmer
CV403	25p trimmer

SEMICONDUCTORS

Q401,2	BF256
Q403	BC109C
IC401	733

MISCELLANEOUS

SW401	4p3w rotary switch
SW402	Wafer-switch assembly
SW402a,b	1p12w make before break wafer
SKT401	50R BNC socket

PARTS LIST

Y2 board

RESISTORS (all ¼W 5% unless stated)

R501	68R
R502	1M, 1%
R503,10,16,17	1k, 1%
R504	10k, 1%
R505	120k, 1%
R506	91k, 1%
R507	910k, 1%
R508,11	100R, 1%
R509,12	2k, 1%
R513	270R, 1%
R514	82R, 1%
R515	22R, 1%
R516,17	1k
R518	2k2
R519,20	10R
RV501	470R preset

CAPACITORS

C501	68n, polyester
C502	680p, ceramic
C503	100p, ceramic
C504	8p2, ceramic
C505	27p, ceramic
C506,8	10n, ceramic
C507,9	22µ, tantalum
C510	56n, polyester
C511	100n, polyester
CV501,2	12p trimmer
CV503	25p trimmer

SEMICONDUCTORS

Q501,2	BF 256
Q503	BC109C
IC501	733
IC502	4066

MISCELLANEOUS

SW501	4p3w rotary switch
SW502	Wafer-switch assembly
SW502a,b	1p12w make before break wafer
SKT501	50R BNC socket

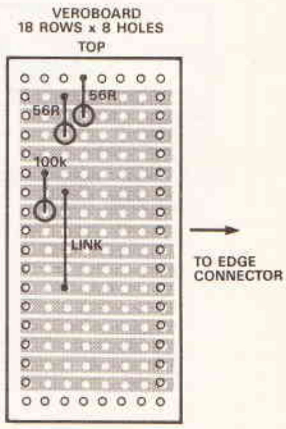


Fig. 19 Temporary setting up link board for position 4 on motherboard

ETI

VAL'S BADGE

Not one to miss out on a bit of fun, ETI brings you the talking point of the year. Wear it on 14 February and you'll never get rid of probing fingers on that day of new love. Heath Robinson (Keith Brindley's nom de plume *for the month) gives details*

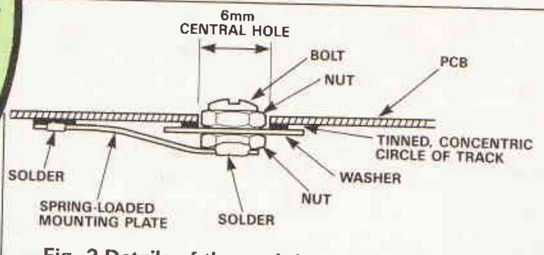


Fig. 2 Details of the push-button switch

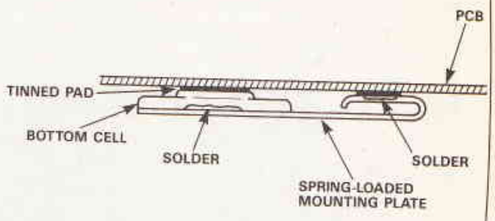


Fig. 3 Details of the button cell mounting

First, a history lesson. The saint, Valentine, referred to on St Valentine's Day, is not one saint, but two. They were both Roman saints: Valentine of Terni, and Valentine of Rome. Both, too, were martyred around the third century BC.

Date used to commemorate them; 14 February, each year, has nothing to do with their lives, however. St Valentine's Day isn't generally thought to be related to the two saints but is possibly connected to the Roman festival of Lupercalia — a distinctly pagan festival.

Origins of Lupercalia are not known, although it *is* known to have been an ancient Roman fertility ritual, celebrated on 15 February, commencing with sacrifices of goats and a dog. After the initial common-or-garden sacrifices, things used to get *really* sticky. It was widely celebrated until 494 AD, when Pope Gelasius the first changed it to the Feast of the Purification.

Nowadays, of course, St Valentine's Day is simply a commercially-organised day of fun, when punters woo their loved ones with cards, flowers, prezzies, and so on — all costing considerable amounts of money. Upholding the tradition of fun (don't we always?), ETI now brings you this clever little project allowing you to upstage the manufacturers and distributors of expensive gadgets and other money-wasting trivia. It's a heart-shaped badge, which you simply pin onto your chest, breast, or whatever; preferably to your clothes, not your skin. In the centre of the badge is a button, which when pressed causes the badge to play the tune *Love Me Tender, Love Me True* — yes, the one immortalised by the king of rock'n'roll himself — Elvis Presley. Together, with this as backing, you can now introduce your intentions to your proposed partner in song. And who could refuse such an overture?

Although readers could be forgiven for thinking that such a project would be a complex one, the Novelty Badge is extremely simple to build. Fig. 1 shows the circuit which, as you'll appreciate, couldn't really be any simpler. Heart of the project (excuse the pun) is a chip, which performs all of the difficult electronic functions. The only other components are electromechanical ones: battery, switch and piezoelectric buzzer. All that is required for the chip to do its job is for the user to momentarily disconnect the power to the chip using the push-to-break push button switch. Once power is reconnected, the chip plays the tune.

The chip, a UM66 melody generator, is one of a family of devices all classed under the same number, which generates a range of tunes:

- type 1 — a medley of *Jingle Bells, Santa Claus is Coming to Town,* and *We Wish You a Merry Christmas*
- type 2 — *Happy Birthday to You*
- type 3 — *Wedding March*
- type 4 — *Love Me Tender, Love Me True*

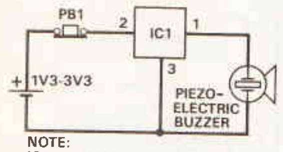


Fig. 1 Circuit diagram of the novelty badge

If you haven't already guessed, the chip is of the same sort which is often used in musical greetings cards of various descriptions: St Valentine's Day, birthdays, Christmas and so on. In cards, the chips are usually chip-on-board (COB) devices (that is, semiconductor dice mounted directly onto PCBs using adhesive and hard-wired with gold or aluminium wires to make the required connections). This form of chip is difficult, if not impossible, to solder in by hand, and is specifically intended for high-volume robotic construction. The COB format also allows extremely thin assemblies — suiting the requirements to allow fitting in a greetings card.

In the form used in the Novelty Badge, the chips are a more conventional plastic transistor-type shape, enabling them to be easily handled and soldered. Requirements for thickness aren't quite so critical for the Novelty Badge as they are in a greetings card, so the thickness of the transistor-shaped chip is not important. The chip isn't, in fact, that much thicker than the piezoelectric buzzer used in the project, anyway.

Although this project has a specific function, that is, a St Valentine's Day badge, the four types of UM66 available are pin compatible. In other words, the PCBs for all types of UM66 are the same, and using a UM66 chip of a different type allows a different tune to be played. Consequently, the badge you make does not have to be just for St Valentine's Day. It could be a birthday badge, a wedding badge or a Christmas badge — the heart-shape used in this St Valentine's Day badge is irrelevant; you could make it circular, triangular, Christmas tree-shaped, church-shaped, birthday cake-shaped, or any other shape you want.

Preamble To Construction

Now the fun starts! Although construction is PCB-based, two points have to be borne in mind and catered for when building the project. First, a power source has to be mounted somehow onto the circuit board. To ensure the PCB is fairly thin and light (who wants to walk around with a car battery pinned to your pullover?) a hearing-aid type of button cell should be used. The chips function when any voltage between 1.3 to 3.3V is applied, which means that a wide range of this type of button cell can be used (in fact, *any* that we know of). Mercuric oxide cells, silver oxide cells, zinc cells can all be used, but we chose a lithium manganese cell — simply because these cells are particularly thin, and have a voltage at the top end of the chip's range (3V). Even though button cells have a strictly limited capacity, you'll find that it will power your badge for a more than acceptable time. Current consumption when playing is not high (less than 0.3mA), and for most of the time, anyway, the project will be in its quiescent state; using less than 1μA of current. You'll probably get fed up of the tune before the button cell runs out of energy! Choice of button cell is one thing, however, mounting it to the PCB is another. We'll be considering this shortly.

PROJECT

Second, some form of push-to-break push button switch mechanism has to be constructed in the project; commercially available push-button switches aren't anywhere near thin enough to use in the badge. We'll be considering this, shortly, too.

These two points have similar consequences, in that they both require makeshift electromechanical connections to be made to the PCB track. Further, the copper which PCB track is made of (although an extremely good conductor when clean) rapidly oxidises in air creating a non-conducting surface layer of copper oxide. So, the first problem to overcome is how to ensure good electrical connections can be made between the required contacts in the circuit.

In commercially-produced PCB assemblies, good contacts are often made by plating the copper track with a non-corroding metal; gold, platinum and so on. But the amateur doesn't usually have such facilities to allow rare-metal plating and another method is needed. Fortunately, we don't have to look far. The very material used to make all permanent connections in PCB assemblies, that is, solder, has a coating effect which enables fairly good contacts to be assured.

Construction

So, the first thing to do is to coat the copper track surface of the PCB with solder. The process, tinning, is simple enough by hand. Apply a hot soldering iron tip to the track for a few seconds, then while keeping the iron tip on the track, feed solder on to the copper. By edging the tip away slowly, while feeding in more solder, you'll be able to cover the copper track surface bit by bit with solder. Pay particular attention to the concentric ring of track around the central 6mm hole and to the button cell mounting pad — when tinned these areas should be as flat as possible to help ensure good contacts. If necessary, reheat these areas until the solder is perfectly flat and smooth.

Next, make the push-button switch which mounts in the central 6mm hole of the board. We used a small bolt, two nuts and a washer to construct the moveable contact of the switch (the fixed contact, of course, is the concentric ring of track around the central hole). File off the end of the bolt, to leave a flat connection point. Now, make a spring-loaded mounting plate from a small piece of springy metal. We found the metal pocket clip of a pen is ideal for this purpose — simply cut the clip to the size you require and bend it to suit. Now, mount the moveable contact into the central hole of the PCB and solder the spring-loaded mounting plate into position, soldering at each end (that is, onto the PCB pad and onto the moveable contact). Fig. 2 illustrates how the makeshift push-button switch fastens together and mounts into the PCB.

Now, make a similar spring-loaded mounting plate to hold the button cell to the board, and solder it at both ends (onto the PCB pad and onto the button cell). Note that the negative button cell terminal must be mounted face down ie, touching the PCB mounting pad. Mounting details are shown in Fig. 3.

Solder in the remaining two components, the UM66 chip and the piezoelectric buzzer, as shown in the overall PCB overlay and wiring diagram of Fig. 4.

Your project is now ready for testing. Press the bolt-head of the push-button switch. As you release it your project will burst into tune.

Finally, glue the piezoelectric buzzer and a fastener of some description to the PCB. The fastener is purely for the purpose of attaching the badge to the article of clothing you wish to wear the badge on. Although a safety pin can be used, the best results will be obtained with a brooch type of fastener, available from any good handicraft shop.

Service

A problem which you may encounter in general use of your badge may be the apparent weakening of the spring-loaded contacts, such that the badge stops working. This is due, in fact, not to the contacts themselves or their spring-loaded mounting plates, but to a physical phenomenon which occurs in many materials, called *creep*. It is the soldered joints at the PCB ends of the spring-loaded mounting plates which are deforming slightly, with pressure and time, so that the contacts move apart until, finally, no physical connection occurs between contacts. Unfortunately, solder suffers considerably from creep. This can be very simply remedied (albeit temporarily, until the next time creep occurs sufficiently to prevent contacts meeting) by resoldering the joints at the PCB ends of the two spring-loaded mounting plates. A more long-term solution is to drill and bolt the mounting plates to the PCB, but this means that bolt-heads for both would be visible from the front of the badge. Make your own mind up whether this is justified.

HOW IT WORKS

The UM66 chip is programmable melody generator with internal ROM. The ROM holds up to 64 notes, such that simple tunes can be stored as sequences of these notes.

The four types of UM66 available, listed in the main text, are simply pre-programmed tunes which are stored in each chip's ROM.

PARTS LIST

SEMICONDUCTORS

IC1 UM66 type 4

MISCELLANEOUS

PCB

Button cell (any type measuring up to 16mm in diameter, and 3mm thick). Piezoelectric buzzer. Bolt (M2.5 or 6BA), two nuts, washer. Metal pocket clips from suitable pens.

BUYLINES

The UM66 chip is available from Maplin, which stocks all four varieties of the chip. All other components are easily obtained from either mail order outlets, or local stockists. The PCB is available from the ETI PCB Service.

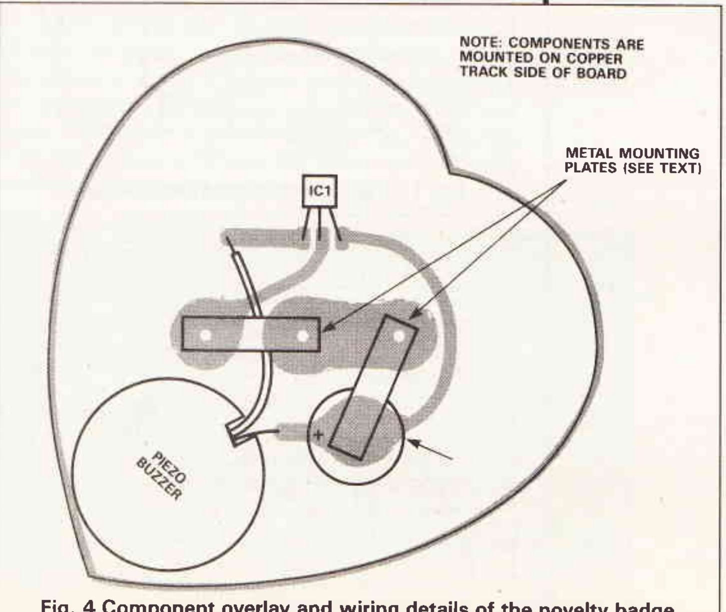


Fig. 4 Component overlay and wiring details of the novelty badge

FLUORESCENTS

You can have more control over your fluorescent luminaries by simple modificaton. Kevin Kirk enlightens us.

Incandescent bulbs are pretty horrendous things, they get very hot, are pretty inefficient (as lights anyway) and have a nasty temperature coefficient which makes controlling them, electronically, a chore. Fluorescents on the other hand are nice, gentle, fuzzy sort of creatures with lots of soft light output, virtually no heat, efficient in conversion of electricity into light and they come in all sorts of shapes and sizes. They have also earned themselves an unfair reputation of being hard to drive and pretty unfriendly to electronics. Well this article is going to prove it isn't true (well not totally true anyway). We are going to explore ways of switching them on instantaneously, flashing them and even dimming them, in fact anything you can do with a normal bulb.

What on earth is it?

A fluorescent tube is actually called a 'low pressure gas discharge tube'. It is a clear glass tube filled with a very low pressure mixture of mercury gas with a little argon. When this gas is ionised by passing a current through it, it produces a large amount of ultra-violet light and a small amount of visible light. The (short wave and potentially harmful) ultra-violet light reacts with the fluorescent powders which coat the inside of the tube, to form long wave, visible light. By changing the composition of the powders different colours of light may be produced. The remaining ultra violet light is filtered out by a filter formed by the glass envelope of the tube.

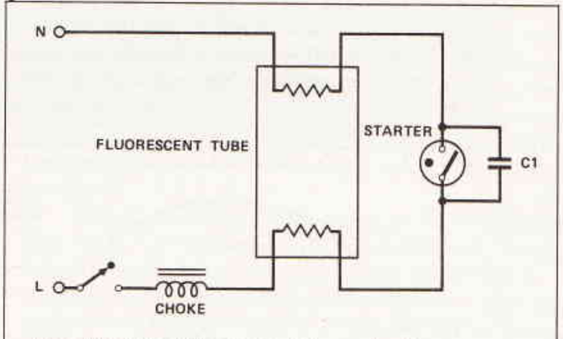


Fig. 1 A typical fluorescent lamp circuit

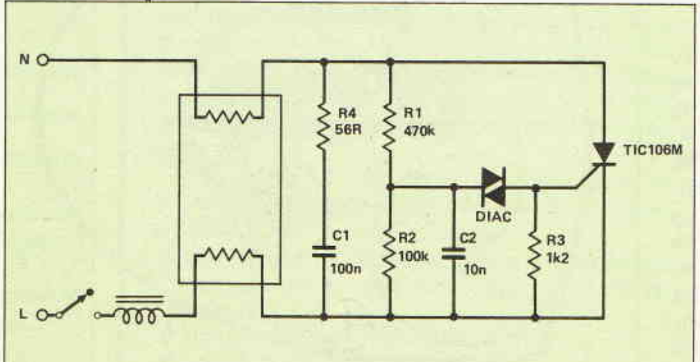


Fig. 2 Circuit with electronic starter

The gas is ionised when 'striking' the tube by passing a fairly large voltage across it until it conducts. This conduction may happen at a lower voltage if the tube is warm which is why if you switch a fluorescent light off and on again virtually instantaneously it will come on very quickly. The manufacturers assist by putting small heaters at each end of the tube which warm up the gas prior to striking. The argon in the mercury assists in the striking as it ionises at a lower voltage and helps to bring the mercury up to temperature.

This is rather like the neon seen in the sodium (yellow) street lights, it ionises first to produce a reddish light and will bring the sodium up to temperature at which point it will 'strike' forming a lower impedance path than the neon, the neon then ceases to conduct.

Back to our tube, once it has started, it can be sustained by a fairly low voltage (around 70 volts), if the full mains voltage was left across the tube its internal resistance will go down, thus increasing the current which in turn makes the gas hotter so reducing the resistance again etc. This means that some form of current limit is required and so a choke is put in series with the tube.

The reason for using a choke rather than a resistor is that the choke will actually be providing a reactance rather than a resistance, reducing the heat dissipation (it upsets the power factor) and secondly it may be used with a starter, to produce a high ignition voltage. The choke also helps to suppress the CW interference the tubes generate. Figure 1 shows a typical fluorescent light set up. Note the capacitor across the starter, this helps to suppress the RFI produced by the ignition voltage and prevents the starter from being welded together by the same ignition voltage. The starter is a hellium filled lamp with bimetallic contacts which are normally open. When the lamp is switched on, the entire mains voltage appears across the starter, which causes the helium lamp to light. The design of this lamp is such that it will only pass about 100mA. This current heats up the lamp which in turn heats up the bimetallic strips. These bend until they touch. At this point the helium lamp is short circuited and is extinguished.

The heaters will now come on and the choke 'charges up'. Meanwhile the bimetallic strips cool until they spring apart, the current to the coil is then abruptly removed. The effect of this is for the coil to produce a large back voltage which is applied across the tube. This causes the lamp to flash and if the gas is sufficiently hot it will ionise and the lamp will light. If not the cycle is repeated until the tube strikes, if ever.

As the tube ages, it becomes more difficult to strike, eventually it fails to strike at all. Once the tube is excited, its resistance is lower than the starter lamp so it will ensure that the starter will not come back on. This process is very slow, resulting in the tube flashing on and off when it is first turned on.

So the first thing we should do is to replace the mechanical starter with some form of electronic one.

Philips, the electronics giant, came up with a neat little circuit they patented (1223733) as shown in figure 2. It is fairly quick but not that quick at turning on the tube and not much good for what we want to do later. However it gives us a clue as to how to do it properly if the circuit operation is described. Essentially when the lamp is first turned on, the full mains voltage is applied across the circuit. If the mains happens to be going through a positive cycle then the voltage at the junction of R1/R2 rises until it is high enough (30 Volts) to turn on the diac. This switches on the thyristor which turns on the heaters and passes lots of current through the choke to 'charge' it up. On the negative half cycle, the thyristor turns off and C2 is supposed to resonate with the tube to produce around twice the mains voltage to strike it. Note the use of R4 as a 'Q killer' to stop the voltage rising too high. If the tube doesn't stay alight then the process is repeated 50 times a second until it does.

As before, the voltage present across the tube, when alight, is too low to turn on the diac. The circuit will switch off. At this point it is worth exploring other ways of turning on the tube quickly.

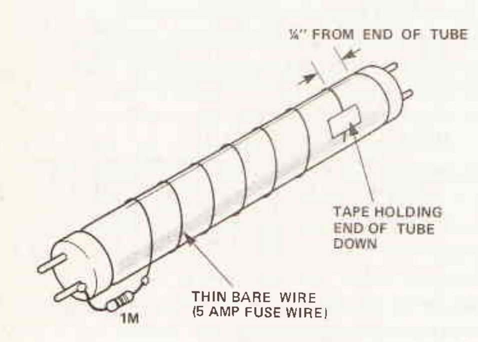


Fig. 4 Making a self starter tube

The quick turn on

There are a couple of ways of turning on a tube very quickly. The first involves the use of a metallic strip running all the way along the outside of the tube, this is connected to one of the terminals via a very high value resistor. When voltage is applied, the full mains voltage appears across the glass at one end and the gas ionises very rapidly in the large Electric field produced. The conductive strip ensures that the now ionised gas is evenly distributed along the tube (this is how xenon tubes, used in strobe lights, are 'excited').

This type of tube, called a self starter, can be struck without a starter as long as the heaters are kept on, by the use of a special heater transformer or a couple of low voltage (6 Volt max) transformers (see figure 3). Don't be tempted to use two windings from the same transformer as the full mains will be between one winding and the other and they may short out unless wound on different bobbins. Philips make a special heater transformer for this job.

You can make your own instant starter tube by connecting a 1M resistor to one of the terminals and winding a piece of wire around the tube connecting one end to the resistor and sticking the other end down to the tube with tape (see figure 4). We will return to this later.

The other way of getting the tube to strike quickly is to raise the voltage across it until it has to strike. The lamp will stay alight with a lower running voltage. This system is used very successfully in portable 12 Volt fluorescent lamps, which tend to strike very quickly. Figure 5 shows a classic circuit which consists of a blocking oscillator that acts as a voltage step up circuit. The circuit operates by having a proportion of the

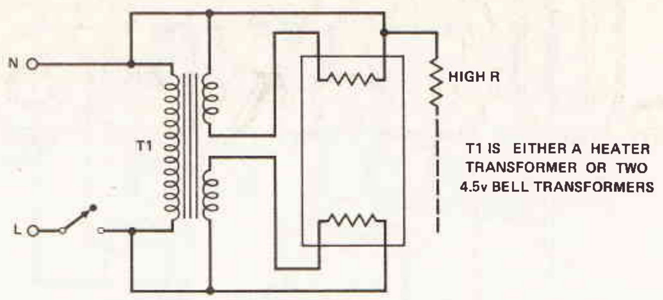


Fig. 3 Self starter fitting

primary current being fed back into the base of the transistor thus ensuring continuous oscillation, R1 provides the base bias. The transformer secondary output voltage, with the tube off, will tend to rise to a very high value which will eventually be enough to strike the tube. Once the tube is alight it will draw current from the transformer and decrease the voltage.

Note, the heaters are not connected, in fact this circuit may be used to give a new lease of life to old tubes. What we want to do is create this sort of effect, but without the need for transistors and transformers. For this we can use a physical effect called resonance. If a circuit consisting of a coil and a capacitor are placed in series (or parallel) there will be one frequency at which the resulting output voltage will rise rapidly. This is called the resonant frequency. The electronic starter used this effect, but limited the Q. What we want to do is to allow the Q to reach a maximum value so making the voltage across the tube over 1kV. The tube will strike instantly. Figure 6 shows how simple this circuit is, just replace the starter with a good quality polyester capacitor having an AC voltage capability of at least 600V and a DC capability of 1kV if possible.

When you turn the circuit on don't be tempted to put your fingers near it, it bites!

If the tube doesn't come on to full brightness increase the value of the capacitor and if it flickers then decrease it. A 470n capacitor was a good starting point for 20 Watt tubes. This instant turn on allows us to do all sorts of things with the lights, for example they may be used in sound to light units, sequencers and so on. A favourite of mine is to use the tubes in a seven segment display in an enormous digital clock (16 foot high digits with 8 foot tubes!). There is of course a down side, if you use a triac to turn the unit on, the back EMF from the transformer tends to turn the triac off again, which is tedious. For this reason the circuit in figure 7 can be used, this provides a continuous train of pulses which will turn on the triac again. The circuit is not turned on at the mains zero crossing point so it will be a little noisy, but the choke will limit the noise.

How to be Dim

Dimming fluorescents needs a bit more care than

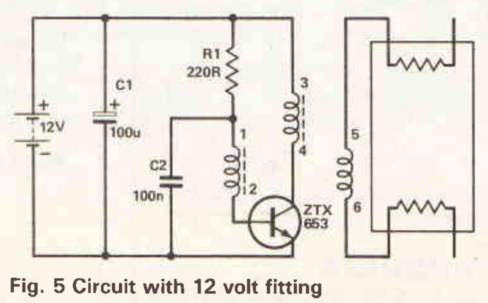


Fig. 5 Circuit with 12 volt fitting

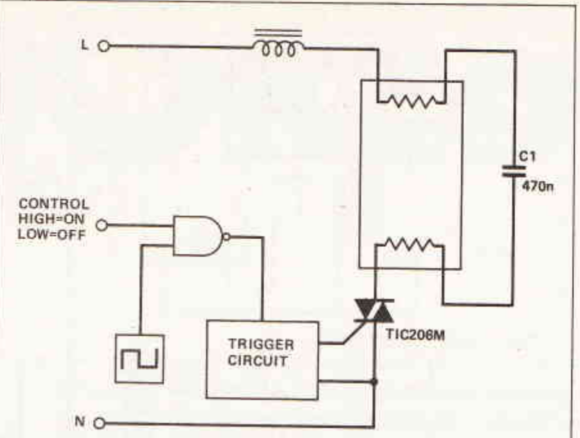


Fig. 7 Retrigger circuit

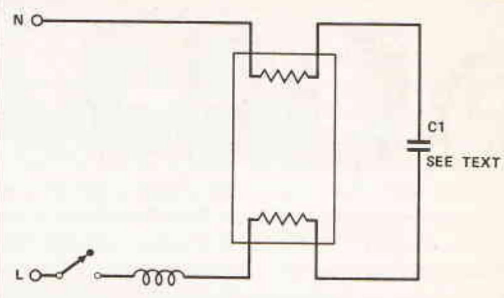


Fig. 6 Simple instant start

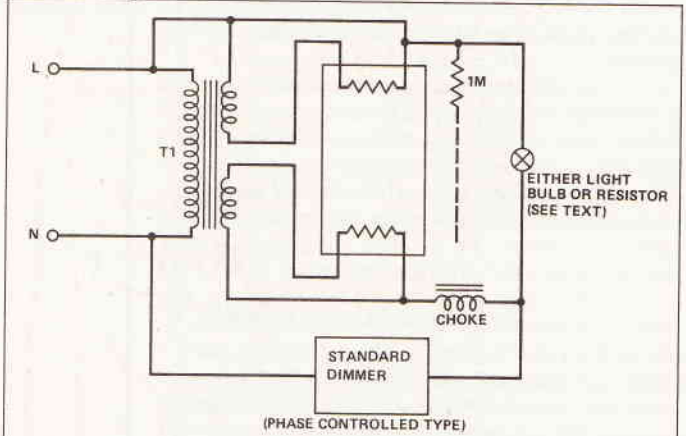


Fig. 8 A fluorescent dimmer circuit

dimming incandescent bulbs. The two problems are that the tube must be able to be brought up to full brightness after being off without the use of high ionising voltages (and starters) and the other is that with a standard phase controlled dimmer the choke tends to keep the triac conducting into the next cycle so it will only dim one cycle. This is not very useful.

The first problem is overcome by using our self starting tube and transformer set up. The second is cured just as easily by simply connecting a normal light bulb across the fluorescent fitting (it has the advantage of producing a very near approximation to sunlight) with a power rating about half that of the tube. If you can't bear the thought of ever using an incandescent bulb ever again then you can use a resistor of about 5k/15w for a 40watt tube, illustrated in figure 8.

Note that all your problems are not over as a fluorescent will not dim as well as a normal bulb. If you try to dim it too much then it will flicker and you will go a long way to wiping out your choke with the DC component thus produced. So you need to set the minimum value on the dimmer (with an insulated screwdriver or preferably with the mains off) to a point just prior to the tube flickering.

OOPS!

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 1=(2700*a)/(vb*fb 2))-0.96*(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.

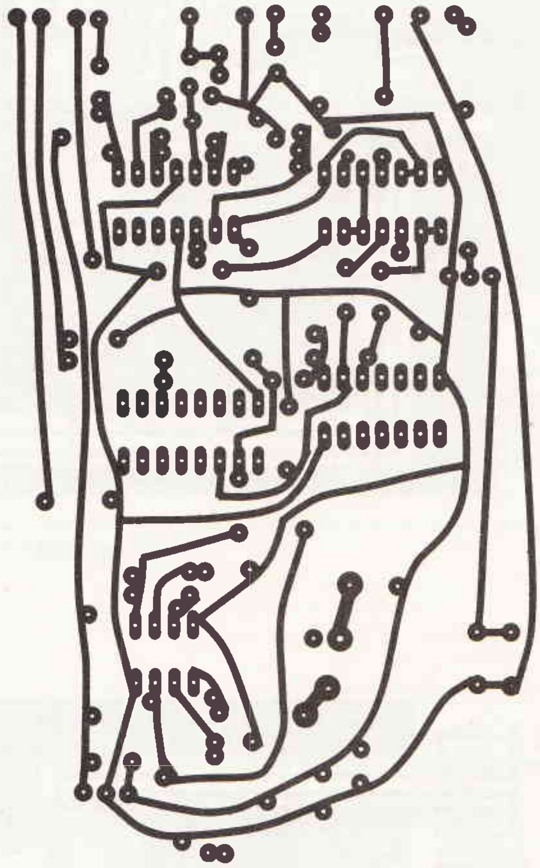
Twenty metre receiver (January 1990)
The foil shown on page 61 was the wrong side. Constructors photographing this foil must use the other side when making a PCB.

Frequency Meter (September 1988)
In the circuit diagram: IC35 ground connection is not shown. Capacitors C25 & 26 should not be polarised. Transistors Q3,4,5 are shown as NPN. IC1 is not labelled. Capacitor C10 should read 2n2. Connections around the area between IC3 & 4 are incorrectly drawn — does not affect operation. On the main PCB overlay: IC4 is unlabelled. Capacitor C10, lower end, is shown connected to ground but should be connected to point C. Connection between pins 3 & 5 of IC9 is missing. Surprisingly, we have reports that this project does work!

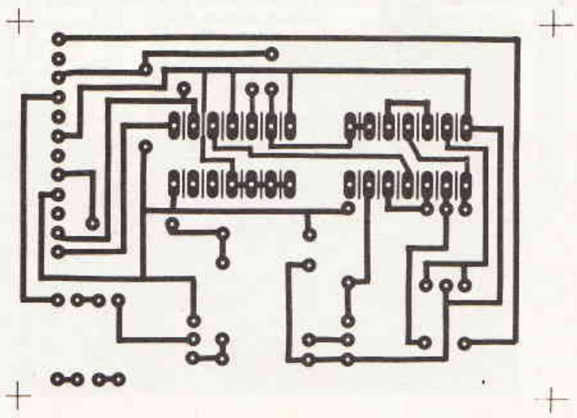
Guitar Tuner (May 1989)
On the PCB overlay: the component labelled IC1 to the right of capacitor C7 should be labelled IC4. IC4 should be labelled IC3. Connection P2 is to the battery +ve supply. Socket SK1 is connected to points P3,4,5, except that these points should be connected via links to the pads directly to their right on the PCB! Diode polarity is not shown. Parts list should contain R5,8,21=47k, R6,22=10k.

Intruderbeam (October 1989)
In the circuit diagram: R9 should read 220R not 220k. Capacitor C1 is shown the wrong way round. Capacitor C2 should be 4μ7, not 2μ2. In the Parts List for the control unit: R6.8=1M; R7=1k; R9=220R; R10=470R ½W.

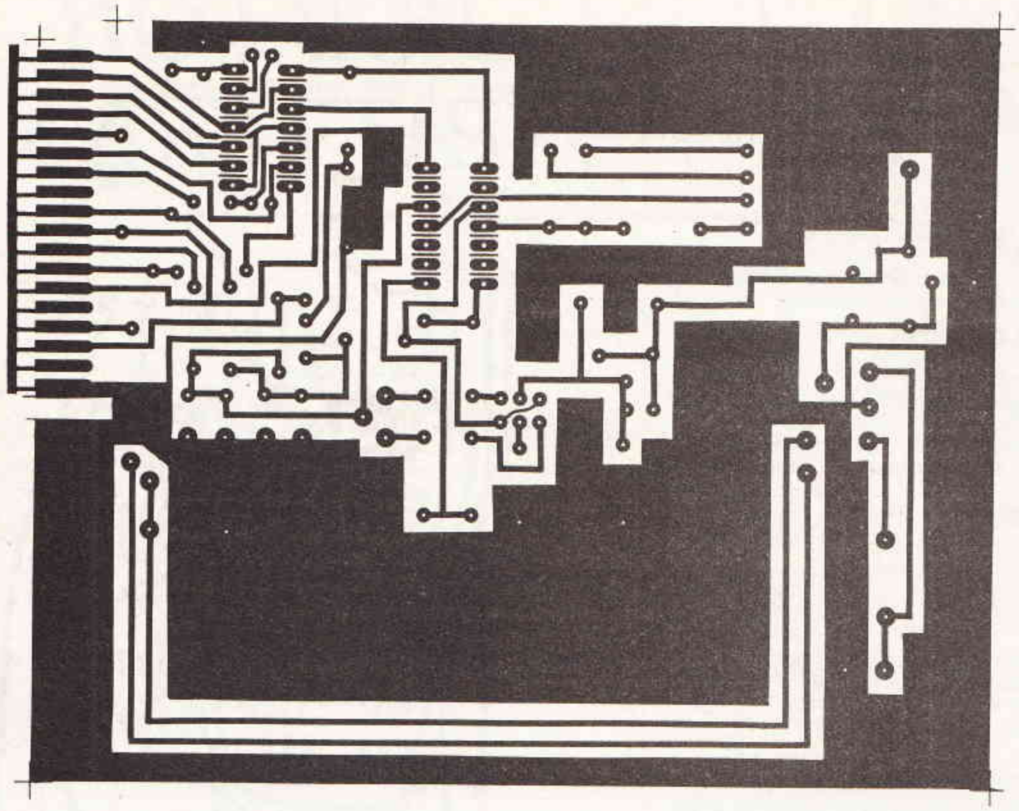
PCB FOIL PATTERNS



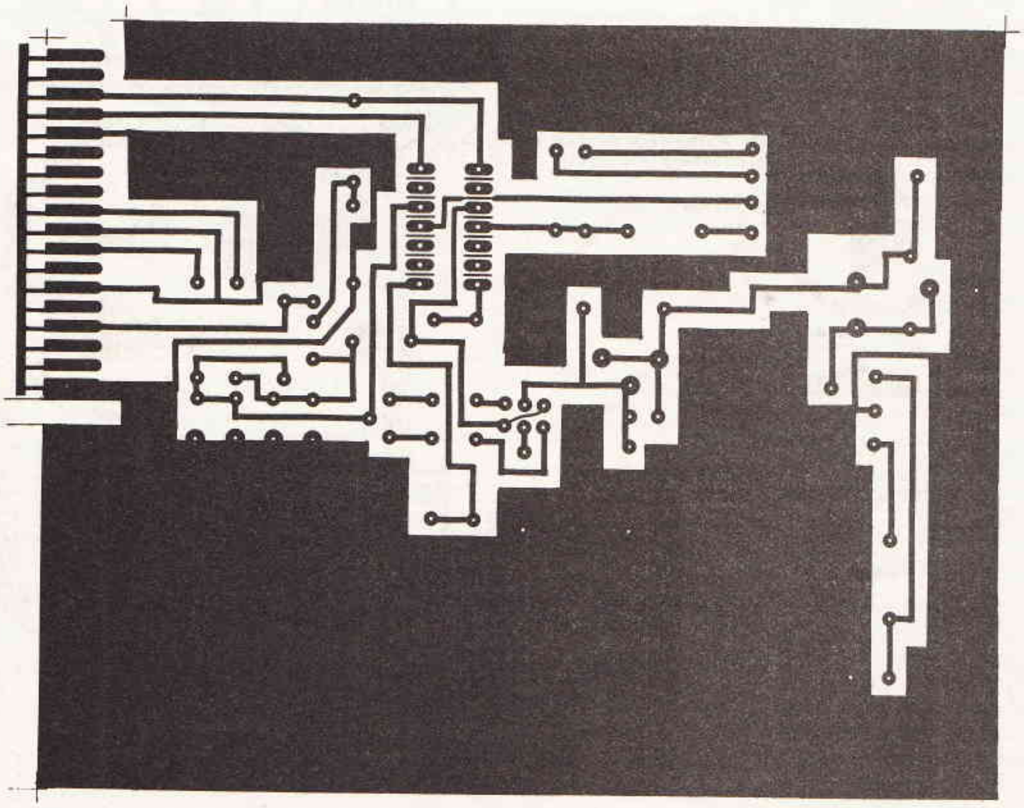
The Water Hole PCB



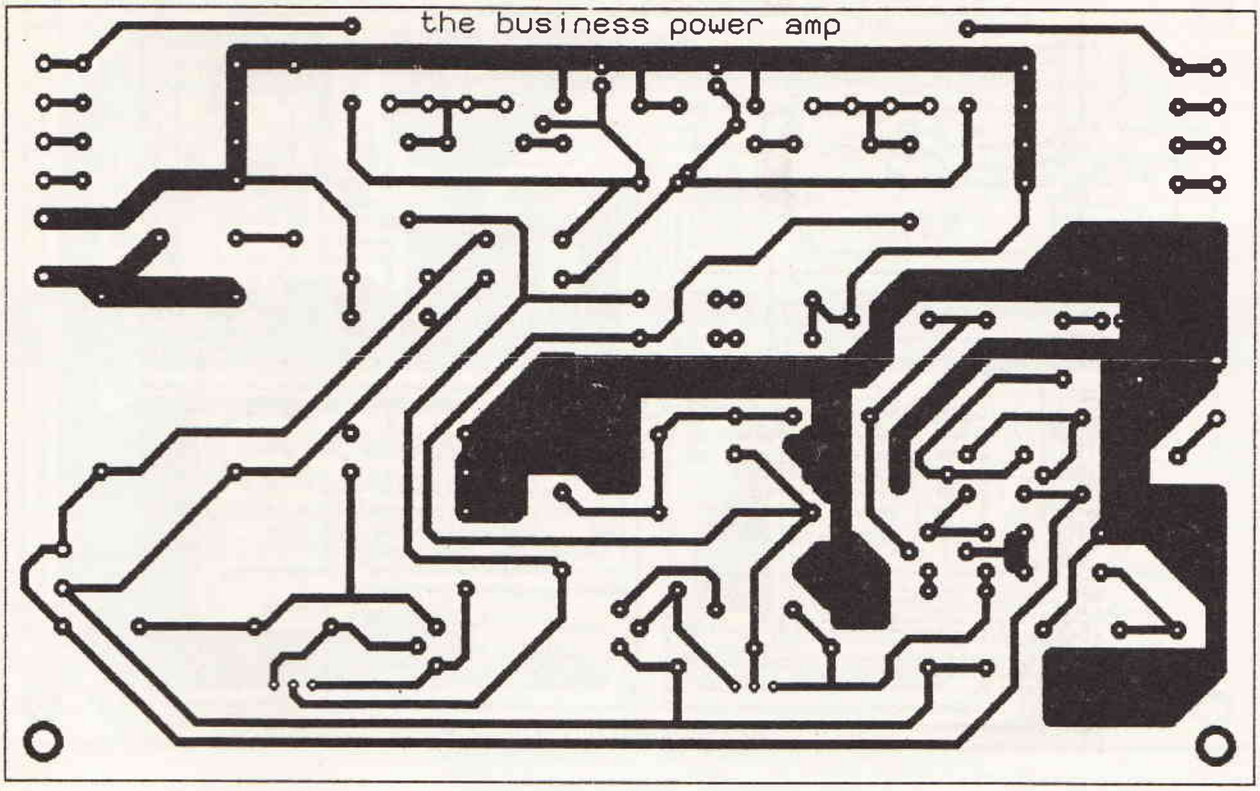
Superscope switch generator module



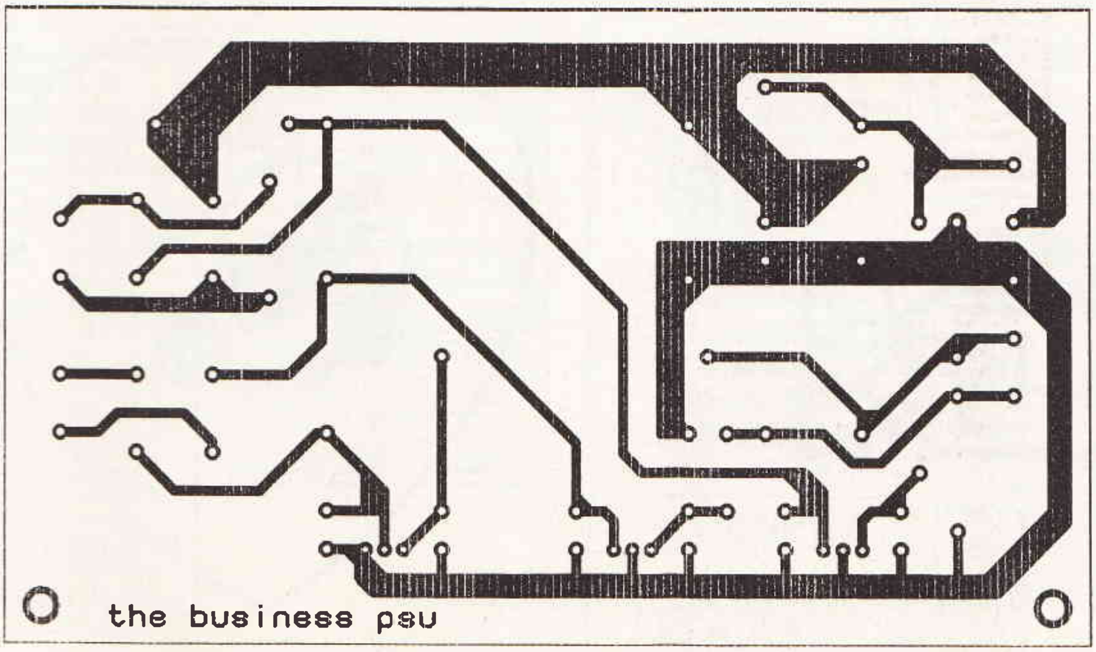
Superscope Y2 input board



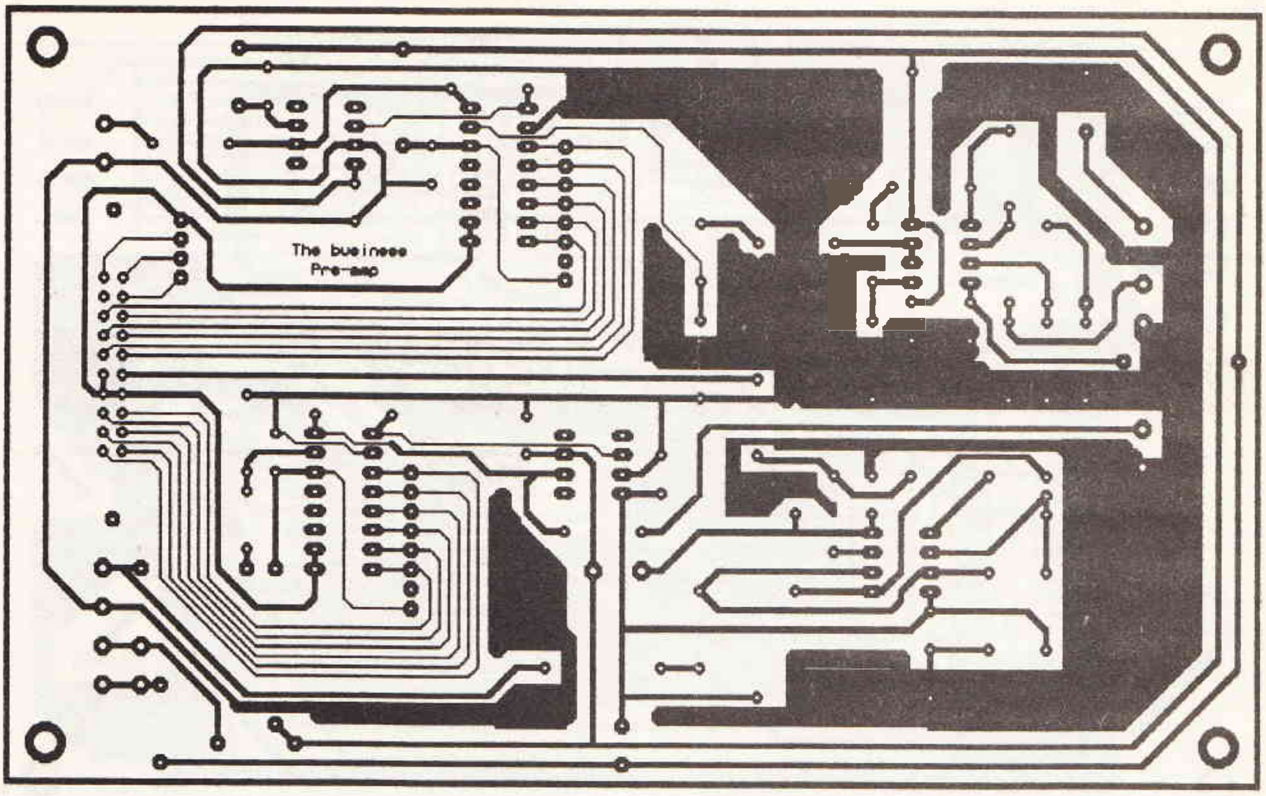
Superscope Y1 input board



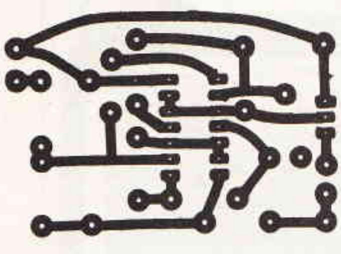
The Business power amp foil

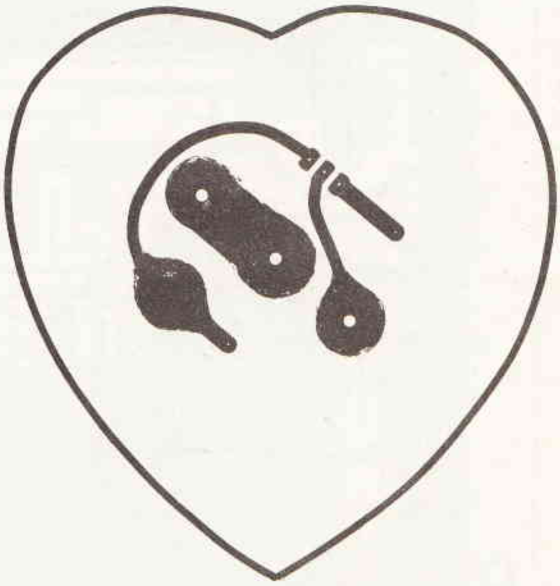


The Business power supply unit



The Business pre-amplifier board


Super Siren foil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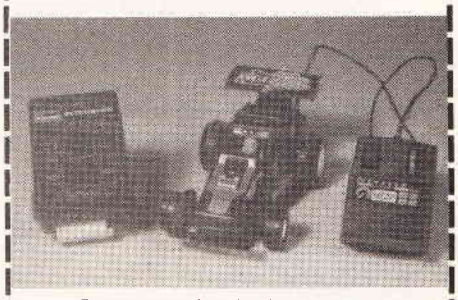

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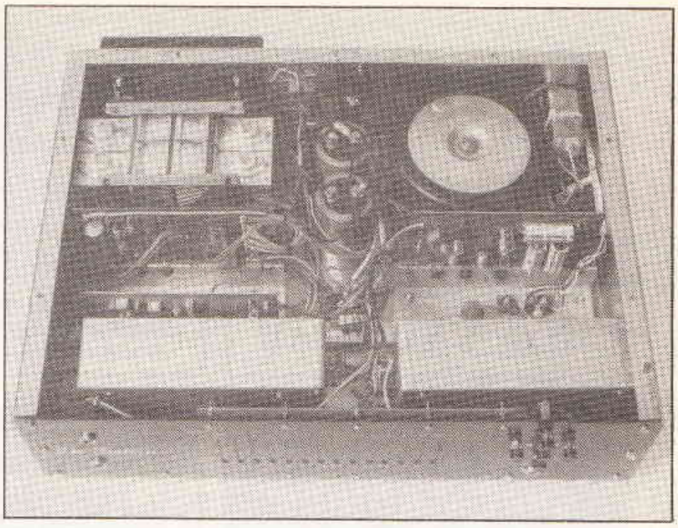
NEXT MONTH

If you have ever wondered how an aircraft can be navigated skilfully through a crowded sky and land its passengers safely all at the guidance of electronics and radio beacons then our next issue could be the one for you. We continue with John Linsley Hood's journey through the elements of radio, examining the parts for good radio reception. With the bass amp, it's 'Business' as usual. It includes the microprocessor control, the watch dog that remembers all filter and volume levels within this impressive amplifier. We also take a look behind the scenes with cable TV and if you fancy designing a power supply right from scratch with all design considerations, then there's no need to look any further than the April issue of ETI.

The very near future holds a bonus for ETI readers. Full colour will start to appear in the centre pages on a regular basis to highlight and exploit some complicated aspects of todays technology, a feature that will be welcomed by many.

Your friendly ETI handymag appears in all good newsagents on 2nd March.

The above articles are in preparation but circumstances may prevent publication



Making the amplifier fit the box is our business

LAST MONTH

What you missed in the February edition of ETI was the first part of Superscope, a dual beam economy oscilloscope, an EPROM Emulator and Ray Marston's second part to this series on Making Waves with plenty of practical sine wave oscillators. More importantly, you missed our free 66 page Top Projects magazine for 1989. It contains some popular project designs we featured last year. It is still available as a back issue through the normal channels while stocks last price £1.50.

ADVERTISERS' INDEX

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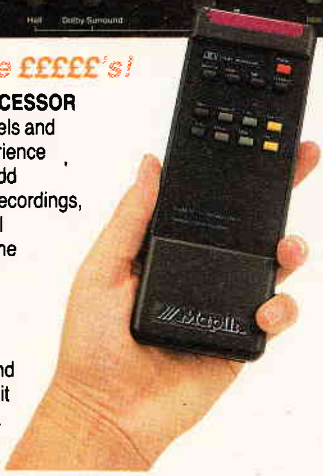

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