ETI ELECTRONICS TODAY INTERNATIONAL

THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY

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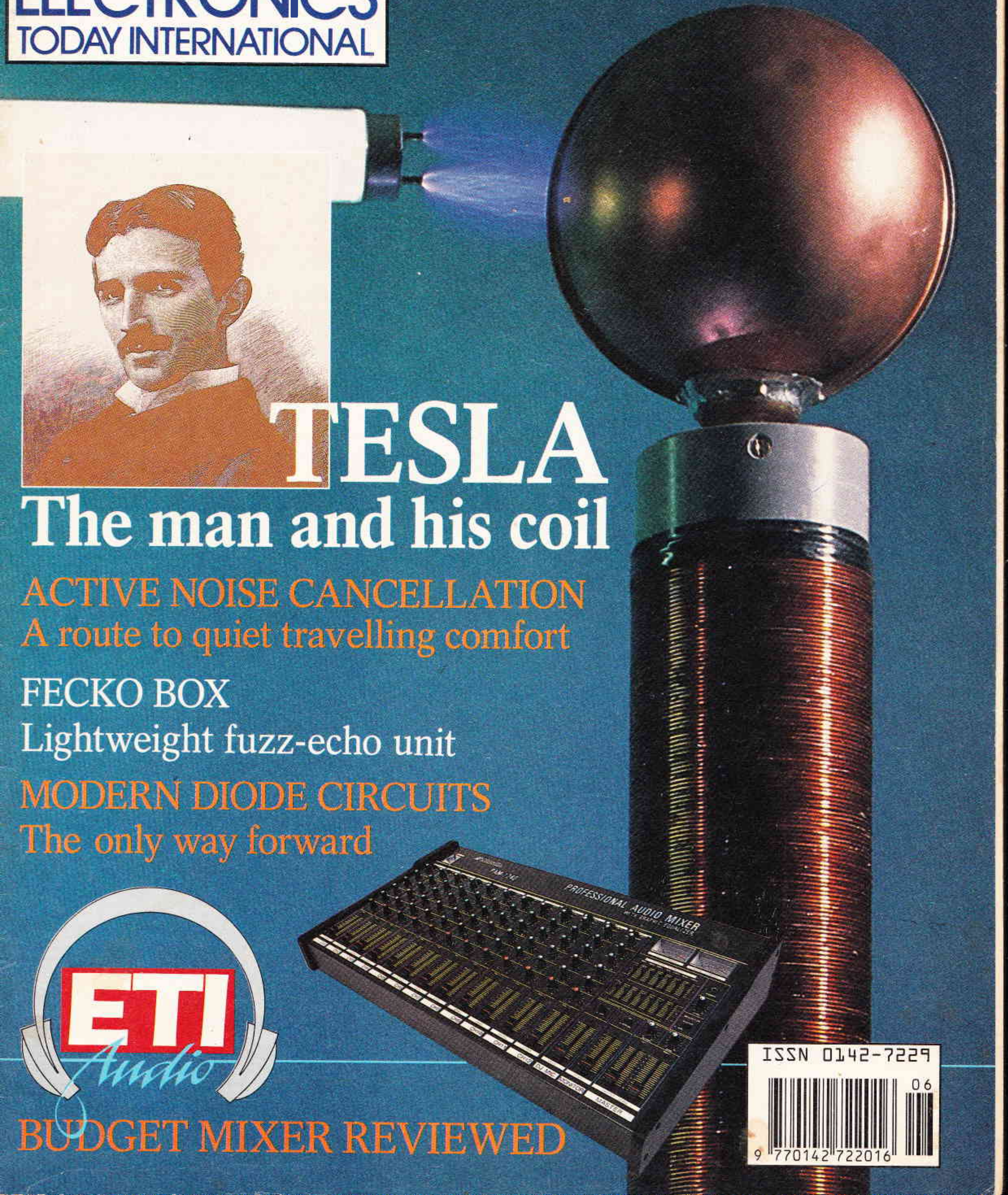
OPERATION SUPERSCOPE
A users guide



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A route to quiet travelling comfort

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Lightweight fuzz-echo unit

MODERN DIODE CIRCUITS
The only way forward

ETI Audio

BUDGET MIXER REVIEWED

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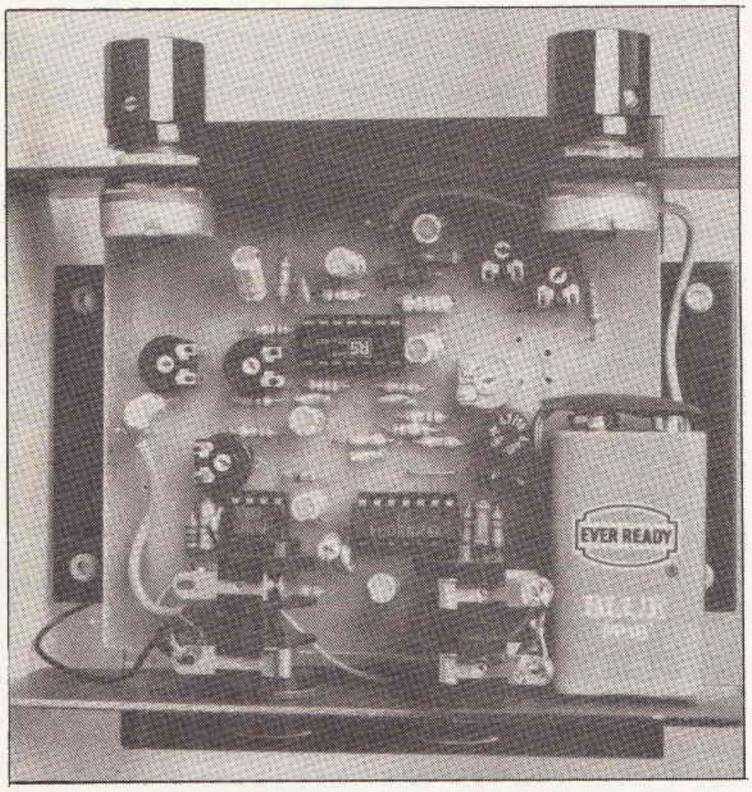

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FEATURES/PROJECTS


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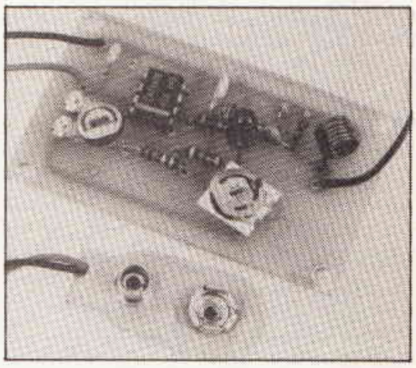
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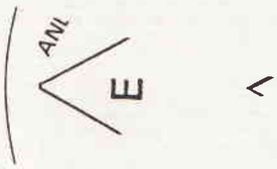


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NEWS

HI HO SILVER

At the Electro Optics and Laser International show last month, 3M were demonstrating the application of their Dry Silver process to digital images.

3M first developed the Dry Silver process in 1964. It provides a method of producing photographic images without the need for chemical solutions. The Dry Silver film or paper is exposed in a similar way to normal film. However, the image is developed simply by applying heat to the exposed film, causing chemical reactions to form a metallic silver image.

Dry Silver technology is now being applied to digital images, in the Lasertechnic 300D Digital Image Recorder. This receives and reconstructs digitally formatted images from any source, with a resolution of 2048 × 2048 in eight values of grey. It may be used in similar applications to a normal laser printer, but produces an output of far higher quality.

Applications of the digital image processing include picture facsimile, meteorological imaging, materials evaluation, fingerprint identification, ultrasound and ocular medicine.

MAKING AN IMPACT WITH ELECTRIC POWER

The prospect of electrically-powered vehicles becomes more attractive with the development of a prototype electric sportscar by General Motors.

The *Impact* develops 85kW (155 hp) of power, has a top speed of 160kph and can accelerate from 0 to 100kph in 8 seconds. It has an action radius of about 200 kilometers.

The Impact has a plastic body with a drag coefficient of 0.19. Despite batteries weighing 395kg, the car's unladen weight is less than 1000kg, similar to that of a conventional midsize car.

The top speed of the car is normally governed electronically to 120kph, allowing the car to reach its maximum range.

In the development of the Impact, General Motors had the benefit of lessons they learned when developing the Sunraycer, their world record solar-powered car. Another advantage over other electric car development projects was that the Impact was designed from the outset as an electically-driven care, rather than as a conversion of a petrol-driven car.

The development work was carried out by the GM Advance Development team in Detroit. GM has applied for twelve international patents for the new technology features on the Impact.

PHONES TO SURVIVE NUCLEAR ATTACK

Never mind that the Cold War is coming to an end. British Telecom intend to be prepared for any emergency, with telephone switchboards which will survive a nuclear strike.

BT has won a major contract for digital switchboards for use in emergencies. The special private branch exchanges (PBXs) could work even after a nuclear explosion.

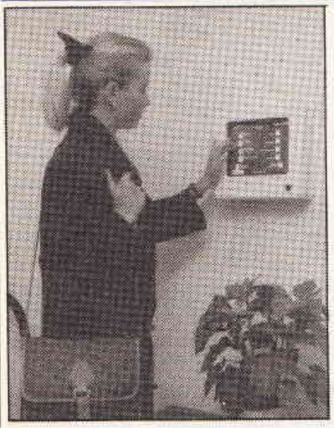
Under the pounds 5 million contract, British Telecom will supply Mitel PBXs to more than 300 local authority emergency centres throughout England and Wales.

The equipment was required to withstand the electromagnetic pulse that follows a nuclear explosion. This pulse would have a catastrophic effect on any computerised equipment. To protect the PBXs, British Telecom incorporated steel enclosures together with line and power protection for all circuits.

Mr Roy Eaton, of the Home Office's Directorate of Telecommunications said: "The successful implementation of this work will provide a modern, resilient network which can provide communications not only for war emergencies but also for peacetime disasters."

But will there be anyone left alive to operate them?

HOME COMPUTER



The computerised home is on the way! Soon you will be able to control heating, lighting, security and appliances from a single console. Further development will include such functions as shopping orders, health monitoring and working from home.

Credanet is an integrated home management system from Creda which allows control and management of appliances and equipment. It will also allow access to internal and external information and financial services. The system will operate through existing house wiring by mains borne communications.

A central controller communicates with other units, through transceivers in each appliance, or from a separate unit in place of the standard mains plug. The controller is a processor with built-in software for basic command and control functions. A touch panel integrated into the large display is used to select operations for auto-control, from programming the heating for the evening to checking the security system.

The display can also be used to show tabular data, such as train timetables, share prices, personal diary, bank balances and so on.

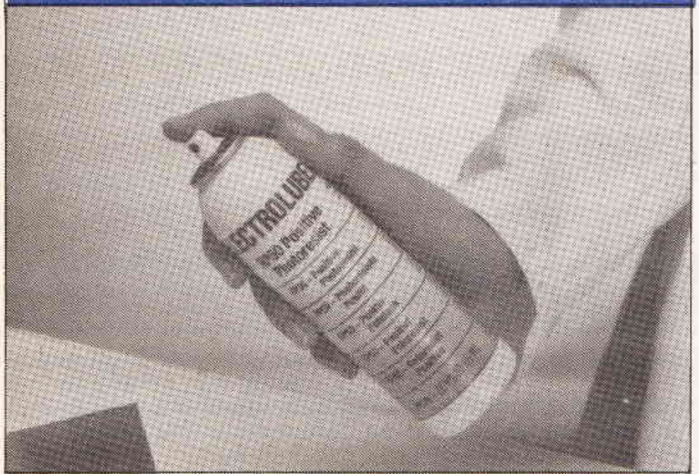
A limited range of Credanet functions can be accessed when you are away from home via the national telephone network. No more holidays ruined by wondering whether you remembered to turn off the heating!

Temperature sensors linked to Credanet allow control of electric heaters either singly or for the whole house. Credanet will ensure that the heating is run to maximise efficiency and can be programmed to operate automatically either on a daily or weekly cycle. It will also store special programmes, for instance when the house is unoccupied during holidays.

Credanet can also be used to control or monitor all security and safety devices, such as intruder detectors, contact alarms, vibration alarms, electric door locks or complete security systems. Smoke detectors can also be incorporated. Special programmes can be stored, for instance, for extra security while the house is empty.

All lighting can be controlled by Credanet, including dimming and varying lighting levels throughout the house. Programming can be automatic on a daily or weekly cycle and special programmes can be stored to operate when the house is unoccupied to give the impression of internal activity.

GREEN CLEAN!



Many solvent manufacturers are finally yielding to pressure to reduce the omission of ozone destroying CFCs to the environment.

ICI has recently launched a range of low emission solvent cleaning plants. Called *Cleanseal* and *Cleanzone*, the plants will reduce use of chlorinated solvents by up to 50% when the system is in use, and by 64% when the system is idling. ICI's range of solvent products includes *Propaklone,* a non-CFC solvent ideal for surface mount applications, which can be used in existing cleaning plants.

Kerry Ultrasonics have introduced an automated ultrasonic cleaning system, the *Aquaclens,* specially designed to use DuPont's non-CFC solvent, *Axarel 38.* Axarel 38 (which used to be known as KCD-9438) provides superior cleaning power to aqueous and CFC cleaning agents, and is bio-degradable.

Another range of non-CFC solvents is the *Re-Entry* range from Bush Boake Allen. The range is based on terpenes — biodegradable solvents derived from wood as a by-product of the paper industry. Their use requires no major redesign of existing cleaning equipment.

In addition to solvent cleaners, an aerosol photoresist which uses an ozone friendly propellant is now available from Electrolube. Electrolube RP50 is available in 75ml and 200ml aerosols, particularly suitable for small production in the laboratory or at home. For more information about RP50 contact Electrolube Ltd. Tel: 0734 404031.

UK STANDARD FOR EUROPEAN TELEPOINT

Six major European PTTs and all four UK Telepoint network operators have signed a Memorandum of Understanding (MOU) to adopt the UK-developed Common Air Interface (CAI) as the basis for Telepoint (CT2) development across Europe.

Telepoint is a telephone communications system which allows outgoing calls to be made from portable phones, by sending radio signals to base stations attached to the national telephone network. Base stations are being established at motorway and trunk road services, in railway stations and in high streets. A call can be made within a range of about 200m from the base station.

The European PTTs are from France, West Germany, Belgium, Spain, Portugal and Finland. The agreement will boost the UK's Telepoint industry, which is already expected to have nearly four million users by 1995. Development across Europe could double that estimate.

The new European agreement could provide export opportunities for two UK based manufacturers, PT and Orbitel, who are currently making Telepoint equipment designed to work to the CAI standard, and will put them in the forefront of Telepoint development in Europe. It will also allow Telepoint customers more choice of equipment, and the opportunity to use their Telepoint handsets abroad.

SHARE AND SHARE ALIKE

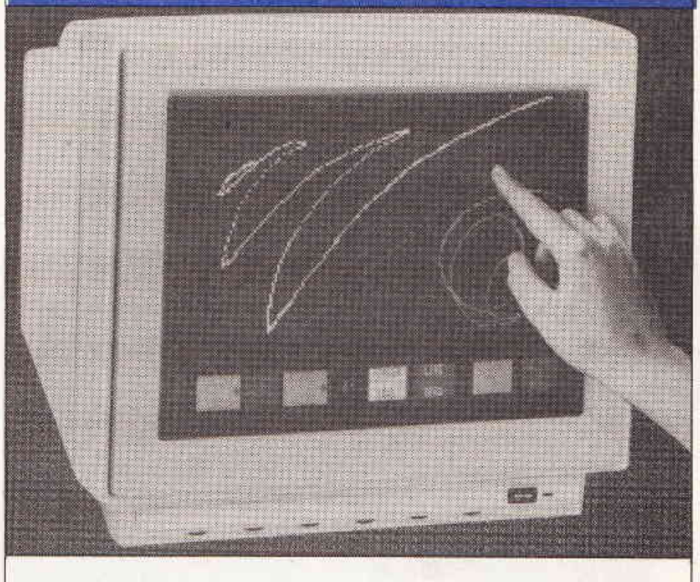
Fax machines are increasingly being used in small offices and private homes, where the cost of installing and leasing an extra telephone line may be prohibitive. A new unit from Teletech International of Denmark allows a fax machine and a telephone to share the same telephone line.

The Teletech *LINESHARE* Model 11-0400 uses filtering and built-in software to determine the states of the attached devices and the telephone line. It has two modes of operation to support almost all automatic and manual fax machines. When a call is received, the unit listens for the calling tone of a fax machine. If the calling tone is detected, LINESHARE rings the attached fax machine, otherwise it rings the phone.

If anyone attempts to make a phone call while a fax transmission is in progress, a busy signal will be heard. A 'silent' function directs all calls to the fax machine so that the phone doesn't ring at night, and switches both fax and phone onto the line if the LINESHARE loses power, so the phone doesn't cease to function during a power cut.

The LINESHARE is approved by the Danish Postal Authorities after parts of the new and still tentative MAP.4 EEC standard, which is supposed to guide design and approval of all devices used to connect to the telephone systems of Europe.

LOW COST TOUCH SCREEN



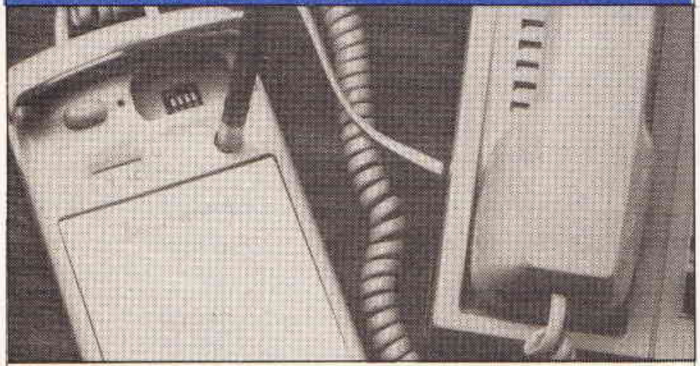
Low cost touch technology is now available from Zenith Electronics for customers who want to incorporate touch systems into interactive applications such as banking terminals.

The lower price allows the system to be used in high volume applications where component costs are a critical factor, and because the system uses fewer parts, it should be more reliable.

The Zenith System allows up to 100 touch points per inch. A 'third dimension of pressure' is available, with up to 16 pressure levels. The system is available on CRTs of 5 inch to 15 inch.

The system works by means of a constant amplitude mechanical wave, set up across the screen by arrays of piezo electric transducers and reflectors. A soft object, such as a finger, attenuates the signal at a specific coordinate, affecting the return signal and allowing the exact position to be determined. The signals used to generate the waves are 16 cycle bursts of 4 MHz and the design of the system prevents interference with any other equipment.

MASKING YOUR IDENTITY



Ever wished you could disguise your voice on the phone, so that you could tell unwelcome callers that you are out? Hong Kong manufacturer Ideatech Industrial have developed the *VocalMask,* a device that enables users to keep their immediate identity secret by scrambling and disguising their telephone voices.

In the event of potentially unwelcome calls, the device shields identity with an unrecognisable voice. However the user can revert to his or her normal voice at any time during the call by sliding a switch.

The VocalMask provides 16 levels of voice scrambling, allowing a woman to sound like a woman or vice-versa, and changing a child's voice to that of an adult. Some advantages are obvious, for example, a woman on her own in a house could disguise her voice as a man's.

But one can foresee great potential for mis-understanding and embarrassment. Business callers may be rude to someone they think is a receptionist when in fact they are talking to a major client. And situation comedies are bound to seize on the mistakes which could be made by adulterous couples telephoning their lovers!

If you want more information about VocalMask, contact IdeaTech Industrial Ltd, Hong Kong. Tel: (010) 852 741 5440.

FAST FOURIER TRANSFORMS!

LeCroy's digital oscilloscopes now perform real-time spectrum analysis using a Fast Fourier Transform (FFT) package. A multiprocessor design allows FFTs to be calculated 10 to 100 times faster than with conventional digital oscilloscopes. 1000-point FFTs are performed in less than 80ms.

The result is a 'live' display that is updated as soon as a signal changes. The display can give instantaneous information on frequency, magnitude, power and phase.

The 'live' response of the FFT package makes it useful for probing high-frequency digital and analogue circuitry, or for monitoring signals which rapidly change frequency such as radar, telecommunications, ultrasonics and acoustics.

HOME VIDEOS GET THE CHOP

It turns out that Camcorder users are becoming more creative and ambitious. Forget the wobbly, jumpy video of your cousin's wedding — many Camcorder users are now editing their films to produce professional looking programmes.

Research by Sony has revealed that three quarters of Camcorder purchasers intend to edit their recordings. The research shows that there is a widespread understanding of the process of video editing which can turn raw footage into finished programmes.

The method adopted by 92% of Sony purchasers is to edit material shot on 8mm down onto VHS for replay.

Sony's research also showed that people buy Camcorders for many different reasons; the most popular are travel at 90.5%, making family records at 72.1% and recording special events at 67.2%.

The research was carried out with recent purchasers of Sony's very small Camcorder, the CCD TR55, so it's not surprising that 77.2% of respondents said that they chose their Camcorder primarily on size. 61.1% chose primarily on weight and 41.1% because of the three hour recording capability.

OPEN CHANNEL

If I've got the quote right, it was Humphrey Littleton who said 'Jazz is the only music that appeals equally to the heart, the mind and the feet'.

And first on the agenda this month is a discussion about the new community radio stations popping up around the country. It just so happens that one of the very first was Jazz FM in London.

These community radio stations (some 23 have either been licenced or are in the process of being licenced) are correctly known as incremental radio stations, simply because they are an increment to areas where local radio stations are already broadcasting. Effectively they are piggy-backed on top of existing services — hence the name incremental. So, for instance, they are cropping up in areas such as London (Jazz FM, Kiss FM, Melody Radio, South London Radio) which already have local radio. Areas such as remotest Scotland and Anywhereshire which do not have local radio at all, thus do not have community radio either.

This seems a unfair, but there is a reason. Once the Government realized that community radio stations should be given the go-ahead (and it was pushed into realizing this, simply because dozens of pirate community radio stations were going to pop up if nothing was done) then ways to licence them were sought. Eventually, this will be done by the new Broadcasting Bill, currently waiting for Royal Assent in Parliament. But, to sidestep this, and show that things were being done, the Government asked the Independent Broadcasting Authority to licence the incremental stations according to a loophole in the current law. Current law is that the IBA has to provide a *range* of broadcast radio services in each local radio area. And it's that word *range* which is the loophole. Apart from actual local radio stations, the IBA is allowed to authorize these incremental community radio stations.

When the Broadcasting Bill gets assent, though, we can expect some 300 to 400 community radio stations to appear in the ether over the next year or so. This will occur as the Bill is administered by a new radio regulatory body, the Radio Authority, set up by the Government with a new 'light touch' approach.

These community radio stations, although local in the true sense of the word, are perceived to serve the community in which they broadcast rather than just to make a profit. Obviously, though, none of these will be in the market to make a loss, so advertizing and/or support from local business and organizations will be used to pay for the initial set-up and running of the stations. An example: London Greek Radio in Haringey, has been financed to the tune of £500,000 by local Greek businesses in the area.

Community radio stations will probably fall into one of two categories, the first being specific music stations, playing only one form of music (Jazz FM) and secondly, particular community service stations perhaps broadcasting specific programmes only in that community's language (London Greek Radio). Whatever happens, they all will have low power transmitters so they can only broadcast to a restricted area, and so they cannot interfere with other nearby transmitters. Frequencies are to be allocated on a cellular-telephone-type arrangement, eliminating inter-cell adjacent channel interference.

Anyone wishing to set up a community radio station along the new Broadcasting Bill lines is encouraged to first get in touch with the Community Radio Association (CRA), an independent organization which came to life back in 1983 to promote the interests of community radio stations. Many of the original pirate stations belonged to the CRA — since then they have become legitimized by the incremental adoption of existing law by the Government and the IBA. Information and advice is available from the CRA at 119 Southbank House, Black Prince Road, London SE1 7SJ. Telephone: 071 582 8732.

Tripping the Light Fantastic

At the recent Electro Optics and Laser International exhibition at the National Exhibition Centre in Birmingham, the company Fibre Data was showing its system for transmission of audio signals to loudspeakers. It's nothing new, really; active loudspeakers coupled to a line-output pre-amped hi-fi centre. Things like this have been around for donkey's years.

What is new, on the other hand, is the transmission medium between centre and active loudspeakers. Fibre Data has used cheap and cheerful polymer optical fibres to carry digital signals — arguably a bit of an overkill. Nevertheless, the idea represents the route top-of-the-range hi-fi systems are probably going to follow, whether the exact method used by Fibre Data is adopted (hence generating cash for the company) or whether the individual major hi-fi manufacturers design their own (more likely).

Public Image

In the USA, publicly-used fax machines have been situated in airports and the like for a while now, but the idea is finally catching on in Britain. At least one UK company (Docu-Fax International) is selling fax machines which are self-service and paid for by credit-card.

Using Mitsubishi innards, the 'payfax' features a writing desk and voice assistance, and is said to be user-friendly. Hotels, garages and supermarkets are likely to be the prime sites for such machines.

Condemned Cell

Finally, I'm going to make a prediction. It's based on a long-time observation of the cellular telephone structure in the UK. Currently, it seems that the system is growing at too fast a rate. Everyone (except me, that is) seems to want to drive down the motorway, posing as they talk into their cellular handsets (illegally, I might add). On a recent trip over a distance of about 70 miles on the M1, I counted no less than 15 drivers doing this.

Anyway, back to the point. The system is about to implode. I say this because of two factors. First is that retailers are being forced into the situation where hardware is being sold at virtually give-away prices. In many cases handsets are being given away. Retailers are hoping to recoup costs in doing this simply by providing the service. In other words, give away the razors, but charge 'em for the razor blades. This can't go on for much longer under the current regime, simply because the razors cost too much.

Second factor is that the other mobile communications networks such as CT2 and PCN will be getting up and standing on their feet soon. This will create even greater competition to the cellular system.

As to how long it will be before this implosion takes place, I can't say. It could be as long as two years. On the other hand, six months is a fair bet. Whatever happens, though, the system will come out leaner and better for it. There are too many people trying to make too much money out of it at the moment. Getting to a leaner system will inevitably though, cost the country a few jobs.

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.

We have an audio Blueprint this month:

Dear Sir,

I have attempted to design a third order passive low-pass 50Hz filter to connect a sub bass woofer to my amplifier. I had to give up because I do not know how to deal with the complex impedance of a loudspeaker, which depends on both electrical and mechanical effects. Is there a method of design capable of handling such factors?

Ian Will, Jordan.

Yes, there is a way, but as Deep Thought (from The Hitch-hikers Guide To The Galaxy) said "You're not going to like it".

This problem is an illustration of the difference between engineers and physicists. The engineer avoids the use of long equations, which have to be fitted sideways on the paper, if at all possible. Forget the mathematically rigorous approach — engineers are usually maths users rather than producers. Normally the first approach is to try to find a design scheme which makes all the inconvenient variables negligible or irrelevant.

Failing this, the engineer with access to a computer would use a simulation tool such as *Spice* to model the effects of diverse parameters, which would probably be measured in the first case. Lacking *Spice*, other approaches might be to use a Smith Chart (normally used for microwaves) or to write a numerical simulation in Basic and let it run over lunchtime.

Crossover Units

As you imply in your letter, only one sub bass unit is needed for a stereo system, because little or no directional information is imparted to the ear by such low frequencies. The use of only one loudspeaker, however, requires a system to combine signals from both channels of the amplifier. Unless a lossy design employing resistors is used, this means that there is a low impedance between left and right amplifier channels at low frequencies. To minimise the circulating currents which would flow (to no good effect), internal filtering and cross connection are needed to run the stereo amplifier in mono as regards bass frequencies.

The problem then resolves itself to that of an ordinary crossover unit, but with most of the circuitry duplicated for left and right channels. This is a problem which loudspeaker designers solve adequately, usually by ignoring the complex nature of loudspeaker impedance and designing as if a resistive load is presented to the ports of the crossover unit. This is not as bad as it sounds, particularly if a second rather than third order filter is used.

Some crossover units incorporate resistors to damp the filter response and make it less sensitive to impedance changes, but this wastes power, which you are short of at sub bass anyway.

There is a disadvantage to the crossover unit approach. The impedance seen by the loudspeaker is high at frequencies above the transition frequency. Any tendency for the loudspeaker to ring at third harmonic frequencies is not damped by the low output impedance of the amplifier. In my view the crossover unit approach is not the best one to use. Indeed, I do not fully approve of crossover units in general for the above reason and for others too long to go into here.

Extra Channel

Perhaps the best way to make the obscure loudspeaker impedance insignificant, without the need to know what it is beforehand, is to use an extra amplifier channel. The extra amplifier is fed with the bass signals from the two stereo channels, using filter pairs as shown in Figure 1. I have shown a second order design because too sharp a transition can cause response ripple around the transition frequency. The scheme here also avoids the lowest bass frequencies being fed to the normal stereo speakers, where they will cause generation of third harmonic (unless these speakers can respond properly to the sub bass, in which case an extra sub bass unit is not needed).

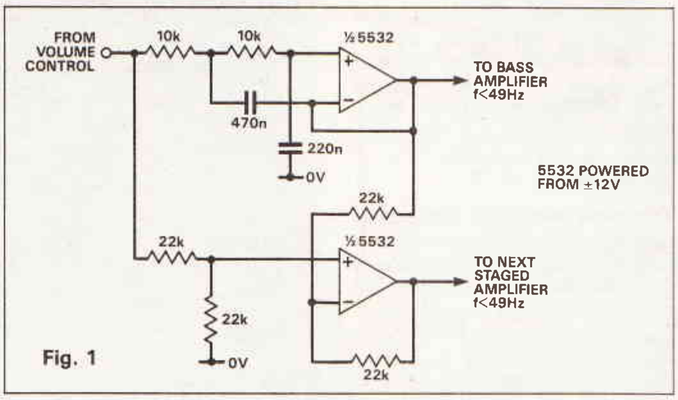


Fig. 1

If it is unacceptable to modify the amplifier, the signal may be tapped from the loudspeaker outputs as shown in Figure 2, but this approach is second best because of the extra distortion present at the amplifier output as well as because the sub bass signals are still fed to the normal stereo speakers. In any event, a single sub bass signal should be generated from a point from a point after the volume control in the stereo amplifier.

The extra amplifier itself is intended for a limited function, and may be optimised for this. It does not need a frequency response which is flat to infinity, because it will not be asked to handle significant signals at above 100Hz. On the other hand, the filter rolls off rather than cuts off abruptly, so that low level signals will be present at up to 100Hz, and these must not be distorted.

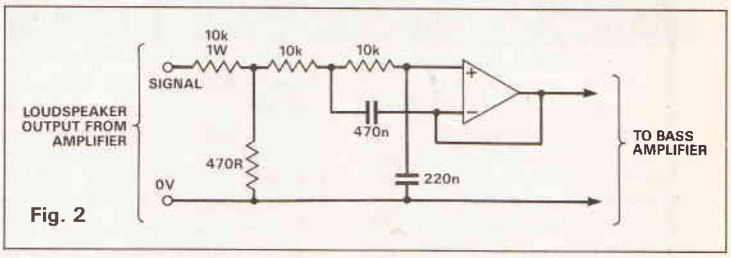


Fig. 2

Equally, because of mechanical non-linearity, the loudspeaker may attempt to generate harmonics of the signal, and the amplifier's negative feedback must do its part in keeping the output impedance low to damp such tendencies. This means that the amplifier circuitry should, ideally, respond at up to a kilohertz or more, and should not generate distortion at any frequency.

A small amount of harmonic distortion distributed over the waveform will be lost in the mechanical distortions of the system, but crossover distortion is absolutely forbidden. Some MOSFET amplifier designs exhibit the figures which are by current hi-fi standards, partly because they have low total negative feedback, but the distortion is relatively unobjectionable. Such amplifiers would be quite suitable for the job.

Damping Factor

To gain the best effect from a sub bass unit, the amplifier should be connected to the loudspeaker with the lowest resistance connection reasonable possible. Don't be fooled by expensive special loudspeaker cables — if you use a fairly short length of resonably thick wire (say 32/0.2) then the connectors will dominate the total resistance.

If it is practical to mount the amplifier on the back of the loudspeaker cabinet, so that all connections are soldered and thus have a stable resistance, you can obtain a further improvement in damping factor and hence lower distortion by use positive current feedback to null part of the loudspeaker's own resistance as shown in Figure 3.

Finally, remember that the better the performance of the sub bass unit, the less it will sound like a normal loudspeaker. Most loudspeaker systems generate significant third (and higher) harmonic output when fed with a frequency signal, which fools the ear that there is more bass than is really present.

Andrew Armstrong

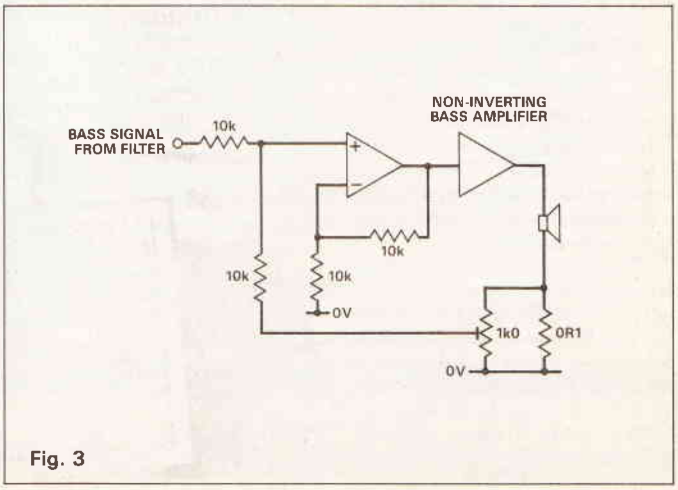


Fig. 3

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EARTH CURRENT SIGNALLING

Part 4: A practical syntonized communication system

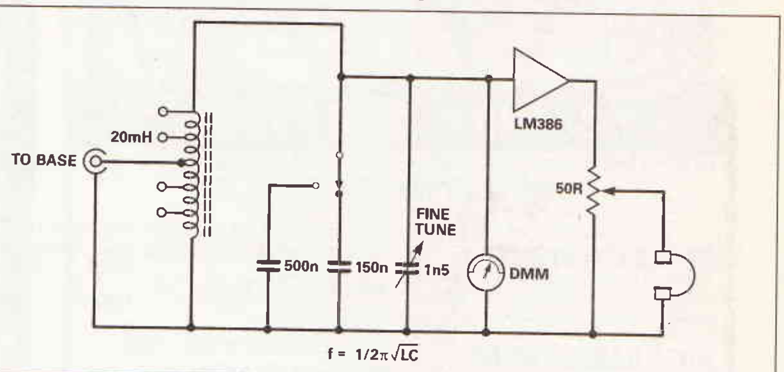

Fig. 1 Schematic circuit for syntonized receiver.

In the final part of his series on ground communication, George Pickworth describes some of his recent experiments with syntonized communication.

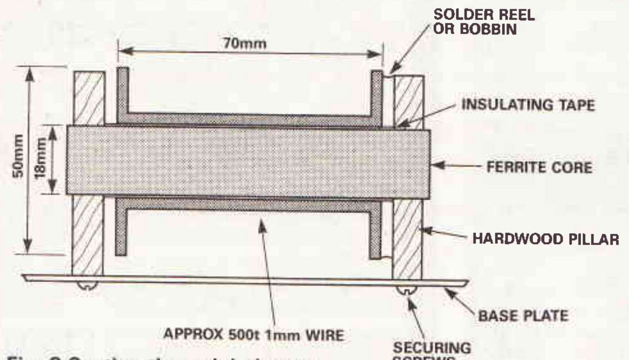

Fig. 2 Section through inductor.

Since the original trials described in ETI over the last three months, further experiments have been carried out with a tuned, or *syntonized,* earth current receiver. This can best be described as a tuned radio frequency (TRF) receiver with a tuning coil and capacitor designed for very low frequencies. The only difference from a TRF receiver is that it does not rectify, but selectively amplifies the input signals.

With the prototype receiver, both 1.5 and 3.0kHz square wave tones (generated by the DC/AC converter) and sine waves (transmitted by the audio amplifier) were received loud and clear at 2000m, with no interference from the 'clock pulses' and radio signals, which seriously limited the range of the original transformer input/high pass filter receiver. 50Hz interference is reduced to a slight 'sharp' buzz under no-signal conditions, but this is almost inaudible when a signal is present. Indeed, by increasing the gain of the amplifier, much greater range should be possible.

The heart of the receiver (Fig. 1) is a 20mH inductor tuned by either a 500n or 150n capacitor, selected by a switch. Fortunately the inductor tuned to almost exactly 1.5 or 3.0kHz, using 20% tolerance capacitors on hand, but in any case, a precise frequency was not necessary for the preliminary trials. The inductor has a resistance of only about 1.5R and with the component values shown, is so selective that even using the signal generator's slow motion drive, it is very difficult to peak at reasonance.

In order to peak the receiver at the transmitter frequency, a triple gang 500p tuning condenser, salvaged from an old domestic radio, is connected with all three gangs in parallel, (total 1n5) across the fixed tuning capacitors. Transmitter frequency is set so that the signal peaks with the variable capacitor set midway.

To provide a fairly high impedance load, the tuner is connected directly to an LM 386 power amplifier IC: the volume control potentiometer is wired across the headphones. As it is difficult to peak up the signal subjectively from the audio signal, a DMM is connected in parallel with the amplifier IC where it serves as a signal strength meter. Under no-signal conditions, the meter reads 0 to 1.0mV rising to 0.25mV with a 3kHz signal from the DC power converter. By incorporating a bank of capacitors selected by a rotary switch, a wide band receiver should be possible. Moreover, there seems to be no reason why an antenna should not be used instead of a base, to receive ELF Hertzian waves.

The inductor (Fig. 2) consists of about 500 turns of 1.0mm enamelled wire, salvaged from an old car dynamo, wound on plastic solder reel, with taps every 100 turns. The 300 turn tap was found to be optimum for the base. The ferrite core is 18mm diameter and 100mm long. A few turns of insulating tape were wrapped around the ends of the core so as to make a snug fit with the hole through the bobbin.

Trials with variable inductance tuning (changing the position of the core relative to the winding) showed that the Q of the inductor dropped dramatically if the core was moved more than a few millimeters from the dead centre so this was abandoned in favour of the variable capacitor. Commercial ready-wound pot core inductors are unsuitable as they have no taps for connection to the base, but a custom wound coil on a large pot core seemed very suitable.

The receiver is well screened from both electric and magnetic fields, and to minimise any possible feedback from the headphones, the base is connected to the receiver by a 10m length of co-axial cable.

Tuning the receiver to audio frequency earth currents was reminscent of the first radio receiver made by the author almost 60 years ago, but more significantly, this simple receiver demonstrated that syntonized earth current signalling at frequencies below 10kHz is indeed feasible, and that opens up all manner of possibilities.

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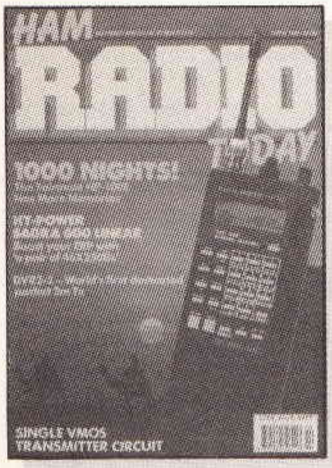

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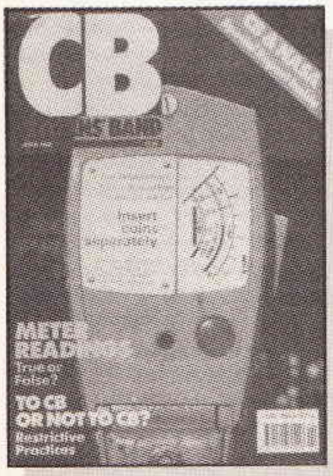

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ETI/7

READ\WRITE

ETI LETTERS

Invasion Of Privacy

Your recent exercises on surveillance gadgets, and for that matter your adverts which include such materials, are anti-social invitations to invasion of privacy. Nobody who has legitimate need for such equipment would have the slightest difficulty in obtaining it, and you are not therefore satisfying any real public need.

When my family was young, they would certainly have been told that any secret use of such equipment would be anti-social and was not acceptable.

K B Wilson
Anglesey.

Cooking Up High Voltages

I don't wish to seem ungrateful, but everybody does pieces on low voltage regulation and there are books you can buy as well.

How about something really useful for a change, namely high voltage regulation — over 35 volts of course, and up to 100 volts.

The reason is to get a really clean supply for HT in audio amps, despite using RF filters and the like. You can get 70 volts of course, by using the outside rails of a split supply, but I would like a bit more if possible. Also a piece on the subject giving the basic theory, instead of burning components as we kitchen table DIY buffs have to do to break new ground!

So how about it, please?

Hugh Haines
Sunderland.

ELF Information Required!

During a recent short trip to Ireland, I read one of your very interesting articles on Earth Current Signalling, which appeared in ETI March 90.

I was really pleased to find such a subject so clearly and accurately described. However, my own experiments with earth current signals have raised some questions.

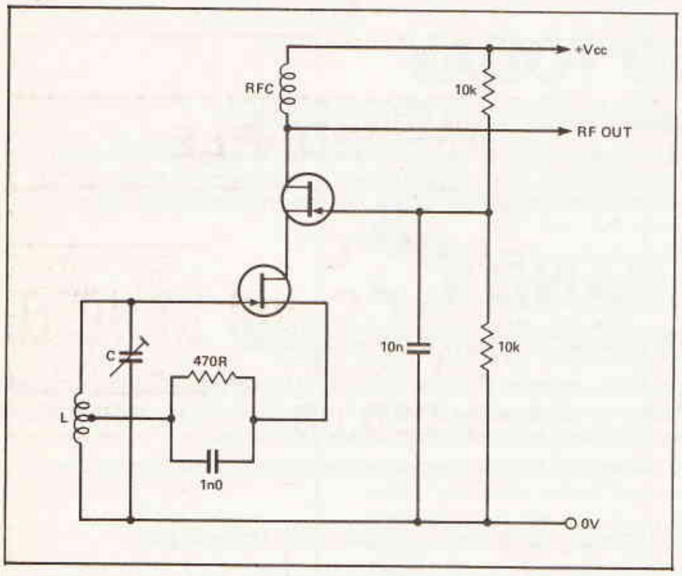
The article refers to "noises originating from miscellaneous static discharges and ELF radio transmitters". Listening to earth signals, I also noticed noises probably due to static discharges. I attributed other noises to current instabilities at the contact between soil and electrodes.

In my case the soil was clay and the electrodes were simply two carbon sticks of length 5 cm and diameter about 7mm, taken from old torch batteries. The distance between electrodes was 50 m. (I did not use metallic electrodes, because they constituted a rectifying contact with the soil. With metal electrodes, I received only the strong local MW transmitter!) The amplifier connected to the electrodes was a transistorised, broad band, audio amplifier without detector (voltage gain about 300). With this system I also received signals from the Omega navigation system on 10.2kHz, but I never noticed any ELF signals.

Can anyone provide more information about ELF signals and ELF transmitters?

To my knowledge the USA ELF transmitter WTF was active in the 1970s. Is it operated at present? Are there other ELF transmitters active today? Do your know frequencies and time tables of such transmission or publications which report such data?

Ezio Mognaschi
Pavia, Italy.



A Couple Of Oscillator Errors

In ETI April 90 some errors appear to have occurred on page 35 in some of the oscillator circuits. Oscillators can be series or parallel fed (with DC supply), thus the oscillator shown in Fig. 8 is a parallel fed Hartley and that in Fig. 10(a) is a parallel fed Colpitts.

The circuit shown in Fig. 8 is certainly not an electron-coupled oscillator since there is no electron coupling. This term is applied to any type of oscillator in which there is electron coupling in the device between the oscillator and its output. Thus it can only be applied to a tetrode or pentode valve in which the screen grid acts as the anode (i.e. collector) and the oscillation is coupled to the true anode by the electron stream. The system thus behaves as a triode oscillator coupled to a pentode amplifier within the same pentode valve. There is no solid-state device which can behave in this manner.

In Fig. 10 the bias developed across the 1k0 source resistor goes nowhere unless the 100k resistor from the gate has its bottom end connected to the OV line. Similarly in Fig. 11 the 5p0 capacitor is blocking the gate of the first FET and should be replaced by a short circuit otherwise the bias produced by the 3k3 source resistor does absolutely nothing.

Finally the signal captions in Fig. 1(a) on page 14 appear to have been reversed.

To end on a more optimistic note, as they say, may I compliment you on a magazine which has improved out of all recognition since its early days.

R G Christian
Frodsham, Cheshire.

John Linsley Hood replies: I am grateful to Mr Christian for drawing attention to the errors in the drawings of Fig. 10 and Fig. 11 of my article in the ETI April 90. The bottom end of the gate resistor in Fig. 10 should, of course be returned to the 0V line, as also should the missing gate return resistor in Fig. 11.

He is also quite correct that an 'electron coupled' oscillator needs electrons, which means that my circuit of Fig. 8 is incorrectly titled unless the amplifying device is a pentode or other multi-electrode valve, where the 'screen' grid can act as a virtual anode.

I realise, in retrospect, that I have been using this term, as a kind of generic name for cathode-source or emitter-coupled oscillators since I was about eleven years old, without thinking of the precise meaning of the description. Presumably one could use a cascode coupled layout, of the kind I have shown below, to give a more nearly exact solid state version of this circuit, with the output isolated from the oscillator function.

I am not sure exactly what kind of circuits Mr Christian envisages for 'parallel' or 'series fed' Hartley or Colpitts designs, but the circuit layouts which Messrs. Hartley and Colpitts patented, and to which they gave their names were quite specific in their use of a tuned circuit between the anode and grid of an amplifying device, in their case a triode valve, with the centre tap of the coil, or of a pair of capacitors connected across this, taken to a point of low RF impedance.

Patent Office Warning

We in the UK Patent Office are concerned with the article by Marc Masson in your April issue in which he gives the impression that the Swiss Patent Office gives an easy route to a worldwide patent.

This is just not so. Moreover, there is a very real danger that the article may lead some of your readers unwittingly to fall foul of national security provisions.

First, there is no such thing as a world patent. To obtain patent rights in other countries you have to file and prosecute a patent application under the National Patent Laws of each country. A Swiss patent gives protection in Switzerland alone and a UK patent is effective only in the UK. Neither will have any influence whatever on how examination is carried out in other countries. There are also a European Patent Convention (EPC) and a Patent Co-operation Treaty (PCT) to facilitate obtaining protection in more than one country — Switzerland is a member of both, as is the UK. As members we all abide by the same set of rules and again the Swiss office have no special position within the EPC and PCT that can simplify procedures.

In fact, the Swiss Patent Office has two levels of examination. Full examination is carried out in a small number of cases, for those inventions relating to textile products and processes and, not surprisingly, horology — this examination is not dissimilar to that in the UK. Marc Masson is alluding to those patents which are given a more limited examination. Since there is not as rigorous an examination they are relatively easy to obtain — **but they do not give the same degree of protection to the inventor.** Patent validity can never be guaranteed and granted patents can be shot down by competitors if they can show the inventor is not entitled to the monopoly claimed. So it is in the inventor's interest to have as watertight a patent as possible and the more thoroughly the application is examined the greater can be the assumption of validity.

As regards the national security aspect, I think I need only quote from our own free hand-out literature on the subject, under the heading

NATIONAL SECURITY: IMPORTANT WARNING:

'Any person resident in the United Kingdom and wishing to apply abroad for a patent must first obtain permission from the UK Patent Office UNLESS they have already applied for a patent for the same invention in the United Kingdom. In the latter case, no application abroad should be made until at least six weeks after the UK filing'.

I realise that this letter must seen somewhat negative. Generally we are delighted whenever attention is given to patents or any of the other intellectual property rights, but I think that Marc Masson's article illustrates the very real possibility of misleading the reader in this highly complex field. Patents often protect investments worth millions of pounds and mistakes cannot be afforded. Moreover, I do not think that any reader who applied direct to the Swiss Patent Office and then found himself threatened with legal action on national security grounds would be too kindly disposed towards your publication.

It is our firm view that, despite the high costs involved, businessmen and industrialists should be encouraged to obtain professional help to assist in the filing of patents, etc.

Your readers might also like to know that the UK Patent Office is presently pursuing an awareness campaign, region by region, with a series of Roadshow seminars. To find out when we will be mounting a presentation close to them, your readers should contact the Head of Marketing and Information Services, The Patent Office, 66-71 High Holborn, London WC1R 4TP (Tel: 01-829 6512).

George Hamlyn
Marketing & Information Services
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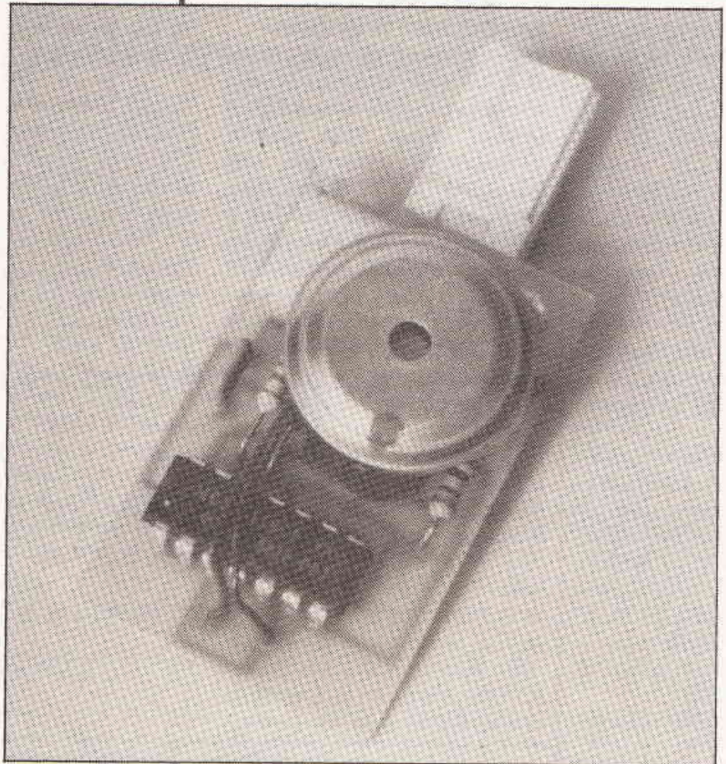
THE TELEPHONE — HOW IT WORKS



Kevin Kirk explains the circuitry behind telephones and gives some project ideas!

TELEPHONE

Virtually every home has a telephone — it provides a vital part of everyday life. Yet few people know how it works, or even the principles behind it. So let's have a look at how telephones work — in the past and the present.

The Telephone

The original telephones were very simple; just a carbon microphone and electromagnetic earpiece with a battery in series (Figure 1). When one person spoke, the carbon granules in the mouthpiece vibrated, changing resistance which in turn changed the current in the line. Kirchoff's law tells us that the net current in a closed circuit is zero, so the same must also pass through the earpiece at the other end.

This unit works fairly well — as long as you don't both talk at the same time, and you don't care about mains pickup or interference. Also you can hear yourself when you speak, which makes you speak more quietly which can be a serious drawback. One answer is to stick the microphone on a stalk and the earpiece on a wire, so you can hold the earpiece away from you ear when you speak.

A better solution is to cancel locally generated signals, without affecting the output level. We can now do this very elegantly using modern electronics, but when telephones were first starting to become popular, modern electronics weren't available. So the ever-resourceful nineteenth century engineers came up with an *anti sidetone transformer*. This was wired in such a way that the signals from the microphone were derived in antiphase to each other through the transformer, creating a common mode nulling effect (see Figure 2). The earpiece was wired onto the same transformer to convert the incoming series mode signals into sound. Nowadays we would use a *duplexor*. In its simplest form this consists of a op-amp wired up as shown in Figure 3. The transmitted signal is applied in common mode to both inputs of the op-amp, which tends to cancel out the signals on the output. The telephone line is connected onto the non-inverting input of the op-amp so it is amplified. R2/R3 sets the gain (in this case R2 = R3 so gain is around 1) and R1 matches the impedance of the line (assuming a low impedance output from the previous stage).

Although relatively expensive, the original transformer had one other really useful feature: it could sink DC current while leaving the AC relatively untouched. This allowed the telephone company to sense when a customer picks up his phone. The cradle switch contacts close and the circuit draws DC current up to 40mA. Figure 4 shows the circuit of a simplified exchange. When the user draws current, the relay corresponding to his line will pass current and come on. Each relay has two coils to maintain AC balance. To avoid affecting the operation of other telephones' relays, each line is decoupled via 2μF non-polarised capacitors.

Nowadays we don't normally use transformers. Instead we tend to use an electronic circuit which mimics a coil. These circuits are called *gyrators*. Figure 5 shows a typical circuit.

The Automatic Exchange

The original exchanges had operators on switchboards. When you picked up your telephone the relay would send a signal to an operator. The operator would answer the call and manually connect the caller to the person he wanted to talk to, via a jack plug and socket system.

This was fine in the days when only about twenty people in town had a phone. You've all seen the films where the filmstar picks up the phone and asks Mary on the switchboard to get him Fred, who instantly answers. Mary, of course, used to listen in on all the calls and would probably pass on the gossip and business news to interested parties to their mutual benefit.

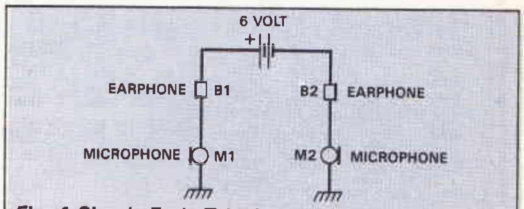


Fig. 1 Simple Early Telephone

Almon Strowger, a funeral director in Kansas city found out that a close friend's funeral was to be handled by a rival funeral director, whose sister was the telephone operator. Putting two and two together, he deduced that many calls destined for him were being passed on to his rival. So he thought out a way of automatically routeing a call, which he patented in 1889. This consisted of a series of uni-selectors which were activated from a dial on the telephone. When the dial was turned, a pair of contacts called *muting contacts* would be closed and another pair would be pulsed. (The muting contacts were closed for two reasons. Firstly to short the local transformer to prevent dialling pulses reaching the earpiece. Secondly, to prevent large voltages being induced by the transformer by the abrupt removal of the DC current. This could cause spurious ringing on the line which could be construed as multiple dial pulses or cause some bell tinkle on parallel connected phones.) On the transistor gyrator, we use a Zener diode to quickly turn on the transistors when the voltage is first applied, effectively shorting out the 'coil'. When the transistors are on, the voltage across Q2 is around 5V, so the Zener turns off and the circuit goes back to being a coil. You could of course just short the lot out with a relay.

1990). The Zener diode ensures that the voltage does not rise above a safe level for operation of the IC.

The rectified AC (there is no smoothing capacitor after the bridge) will produce a warble effect. The tone may be changed by changing R2. The current is low so it should not affect any other phones on the circuit.

If you want an outside bell for when you are at the bottom of the garden, the circuit of Figure 10 might be more in your line, using a bell transformer and bell of your choice. Please keep the Telecom side and your side of the opto as far apart as possible.

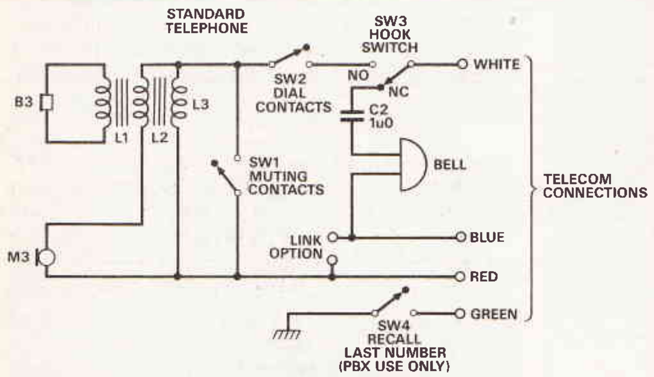


Fig. 2 Early Telephone With Anit-Sidetone Transformer

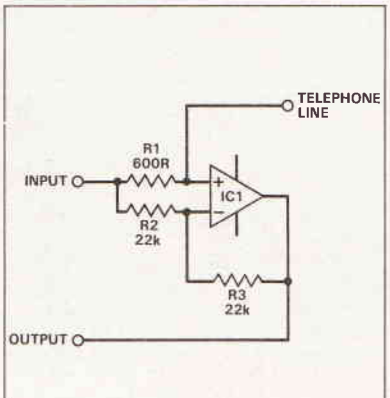


Fig. 3 Duplexor Circuit

The dialling itself is outlined on Figure 6. Note the asymetric pulse waveform. This was originally done because relays take longer to drop out than they do to make. The interdigit pause signals the end of one digit and the start of another.

There is another form of dialling, much used in the USA and slowly catching on here. This is called Dual Tone Multi Frequency (DTMF) dialling. It uses a pair of tones to indicate a digit to be dialled, allowing the system to be very fast (a pulsed digit can take up to 1 second to send plus inderdigit delays). DTMF is especially suited to computerised diallers. A typical dialler is shown in Figure 7a. With its attendant tones it can take input either from a keypad or via a suitable isolated interface from a computer. Figure 7b shows how the unit works.

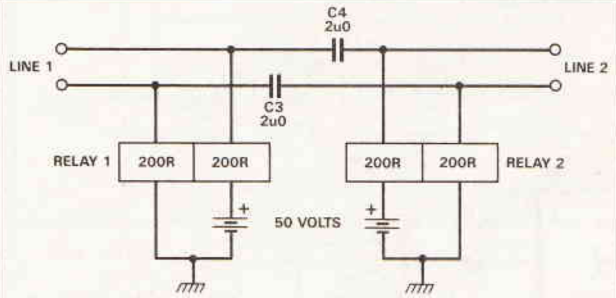


Fig. 4 Simple Telephone Exchange

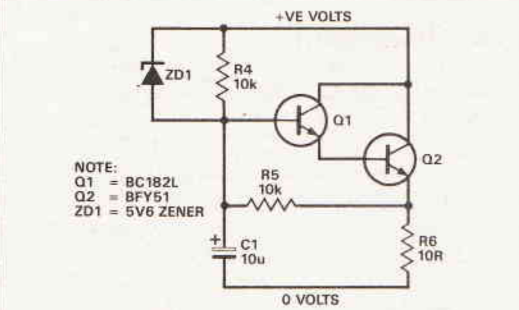


Fig. 5 Gyrator Circuit

The Bells! The Bells!

Now we've covered dialling out, what about ringing in? Bell tinkle was mentioned earlier and can be a problem even if you short out the transformer, because the voltage rises fairly quickly, passing through the DC blocking capacitor in the bell circuit. This may be stopped by connecting the white and blue wires from the telephone together via a 100R resistor during dialling to short out the bell. A relay or opto triac could be used for this.

The bell circuit itself is a simple system, consisting of a bell wired in series with a 1μF capacitor. This ensured that the bell itself couldn't draw DC current, which would appear to the exchange as though the phone had gone off hook. The ring current (or *call arrival indication* as it is called in British Standards) is derived from a voltage source of 63 to 100V at either 16.67Hz or 25Hz with a cadence of: 400mS on; 200mS off; 400mS on; 2s off.

Your Own Extension Bell

It is fairly simple to rig up an extension bell (see Figure 8). This circuit can be plugged into any extension socket and will bleep in time to the ring signal. The operation of the circuit is straight forward. The AC ring signal is passed via C1 and the current limiting resistor R1 into the bridge rectifier. The output of this provides the voltage required to power a small oscillator formed by IC1 (similar to the low voltage alarm in ETI January

To help you, we include PCB layouts for these circuits. The circuit draws slightly more current and is the equivalent of 1.5 REN (the maximum REN on line is 4, a telephone is usually 1).

A Do It Yourself Phone

A real must for the enthusiastic reader! You can put together the circuits described so far, add a single readily available chip from Texas Instruments plus a few odds and ends, and bingo — a telephone! (Figure 12). You can make it in the form of a Royal Doulton teapot or an elephant's foot, to become the envy of your friends.

The circuit needs a little explanation. This is no ordinary telephone, it's a computer-dialled telephone. And by replacing SW1 with an approved relay (for example the OMRON G4D-287P-BT2) which could be connected to a computer output via a suitable transistor, you can make your telephone really

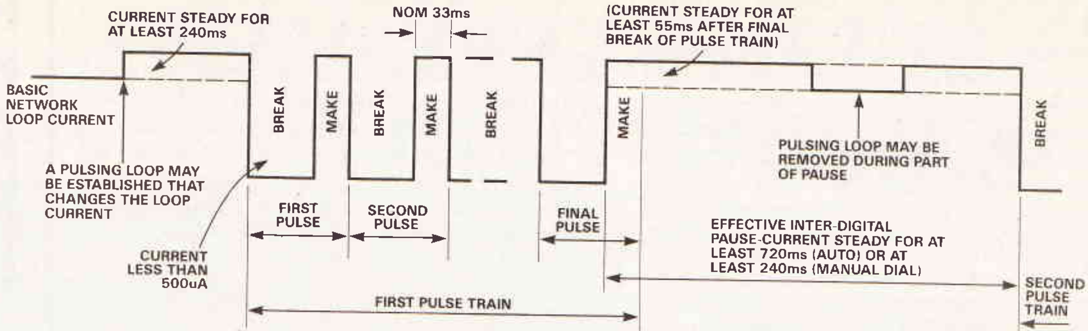


Fig. 6 Dialling Pulses

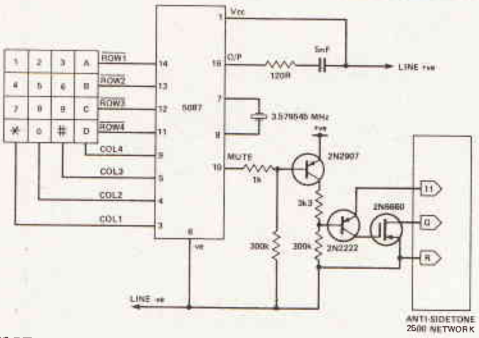


Fig. 7a DTMF Dialler

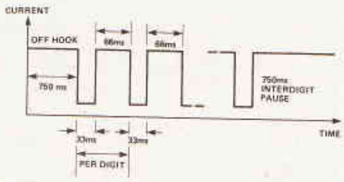


Fig. 7b Pulse Train

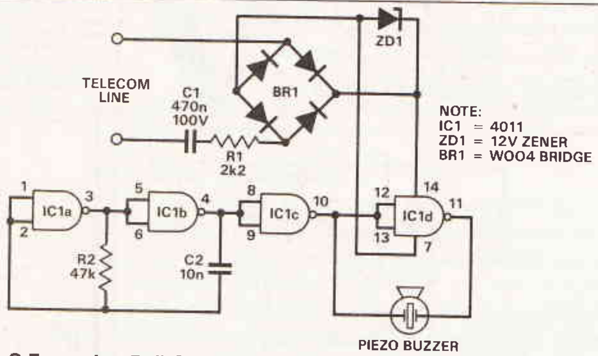


Fig. 8 Extension Bell Circuit

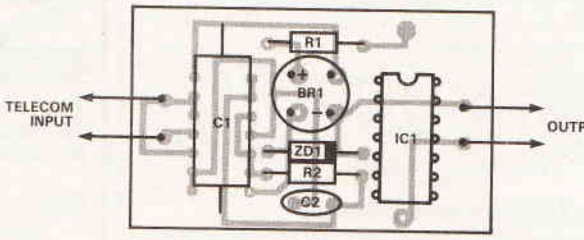


Fig. 9 Extension Bell Component Overlay

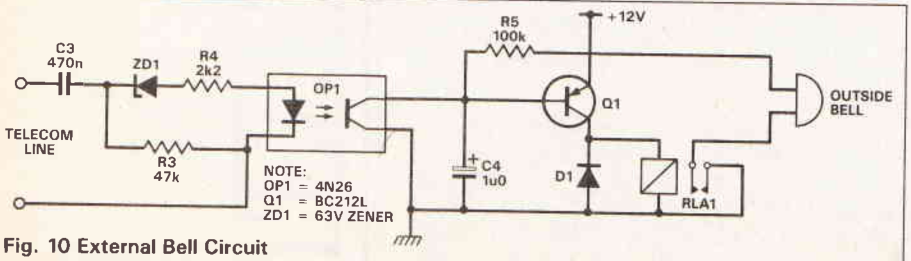


Fig. 10 External Bell Circuit

computer controlled.

The tone dialler is very similar to the one we looked at earlier but as it is designed primarily for computer applications, its inputs are not multiplexed. Instead, all inputs accept a simple low = on.

The input is a serial input to minimise the number of opto isolators. It works in the following way. At the start of the cycle the input on D (data) is high. The clock is taken high and then low again. This initial high starts the timer, creating a timing 'window' which lifts the permanent reset from the 4015. Consequently the first high bit is now clocked into the shift register. A sequence of 1s with 2 × 0s is clocked into the 4015, 1 bit per clock transition. The 2 × 0s correspond to a pair of tones, which represent a number, # (hash) or ★ (star). Table 1 shows this sequence.

Table 1: Tone output table

	C1 (D1)	C2 (D2)	C3 (C3)
R1 (D4)	1	2	3
R2 (D5)	4	5	6
R3 (D6)	7	8	9
R4 (D7)	★	0	#

For example, if you want to send a 5, bits D2 and D5 should be low and all other bits high. Eight bits must always be sent because when the first bit (bit D0) gets to Q3 of IC3:A, the tone dialler is turned on.

The tone dialler will stay turned on until the timer times out and resets IC3, which in turn will switch off the output from IC2.

The timing should be adjusted so that the time window is long enough to allow all eight bits to be clocked in plus 100mS, so the tone is on for 100ms. The computer controls the off timing and it too should be set to around 100ms.

We won't go into great detail about connecting the phone to a computer. However, you can easily connect it to a BBC (or Master) user port, using one control line as data and the other as a clock. The Advanced User Guide for your computer will tell you how. Similarly, with a bit of ingenuity you could connect the phone to a PC via the serial port.

The component values around IC1 have been chosen to match with the average line, so they shouldn't be changed. The possible exceptions to this are the resistors R9 and R10 and the earphone. These components may be replaced by a 600 Ω isolating transformer, feeding a small amplifier to drive a pair of headphones. You could even use a speaker, if you site it carefully to avoid feedback into the microphone input. Another option is to feed the signal into a tape recorder so you can record all your calls.

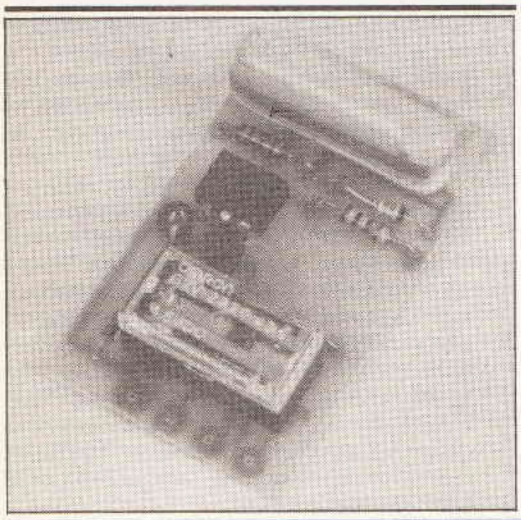
DO also drives a P channel MOSFET which will turn off the voice circuit whilst dialling so you don't get deafened by the outgoing tones.

IMPORTANT

You cannot connect any equipment to a British Telecom telephone line unless it has been approved by British Approval Board for Telecommunications (BABT) and you risk prosecution if you do.
To obtain approval, your equipment must not interfere with the network. This means it must comply with barrier regulations, and its impedance must match the system, with correct output levels and no out of band spectral components.
British Standards BS6305, BS6301 and BS6789 give the relevant information.
You must take great care NEVER to mix BT signals and your signals without a barrier – if you are not sure then don't. Remember that a lot of people rely on the network for a living and they would not appreciate it if you wipe out an exchange by connecting up something you shouldn't.

BUYLINES

The chips mentioned above are all available from Farnell Electronic components (telephone 0532 636311).



PARTS LIST

RESISTORS (all ¼W 5%)	
R1	2k2
R2	47k
R3	47k
R4	2k2
R5	100k
CAPACITORS	
C1	470n
C2	10n
C3	470n
C4	1µ
SEMICONDUCTORS	
BR1	W004
D1	1N4148
IC1	4011
OP1	4N26
Q1	BC212L
RLA1	12V, >120R
ZD1	12V
ZD2	62V

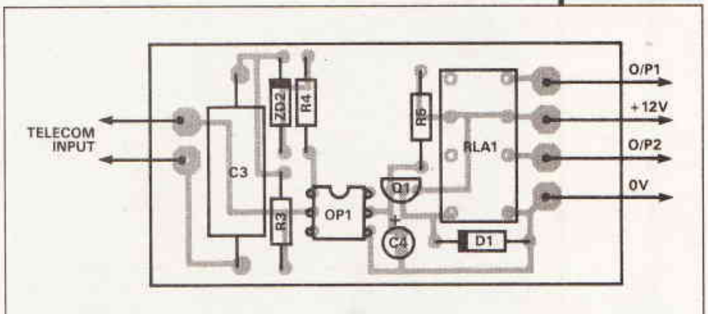


Fig. 11 External Bell Component Overlay

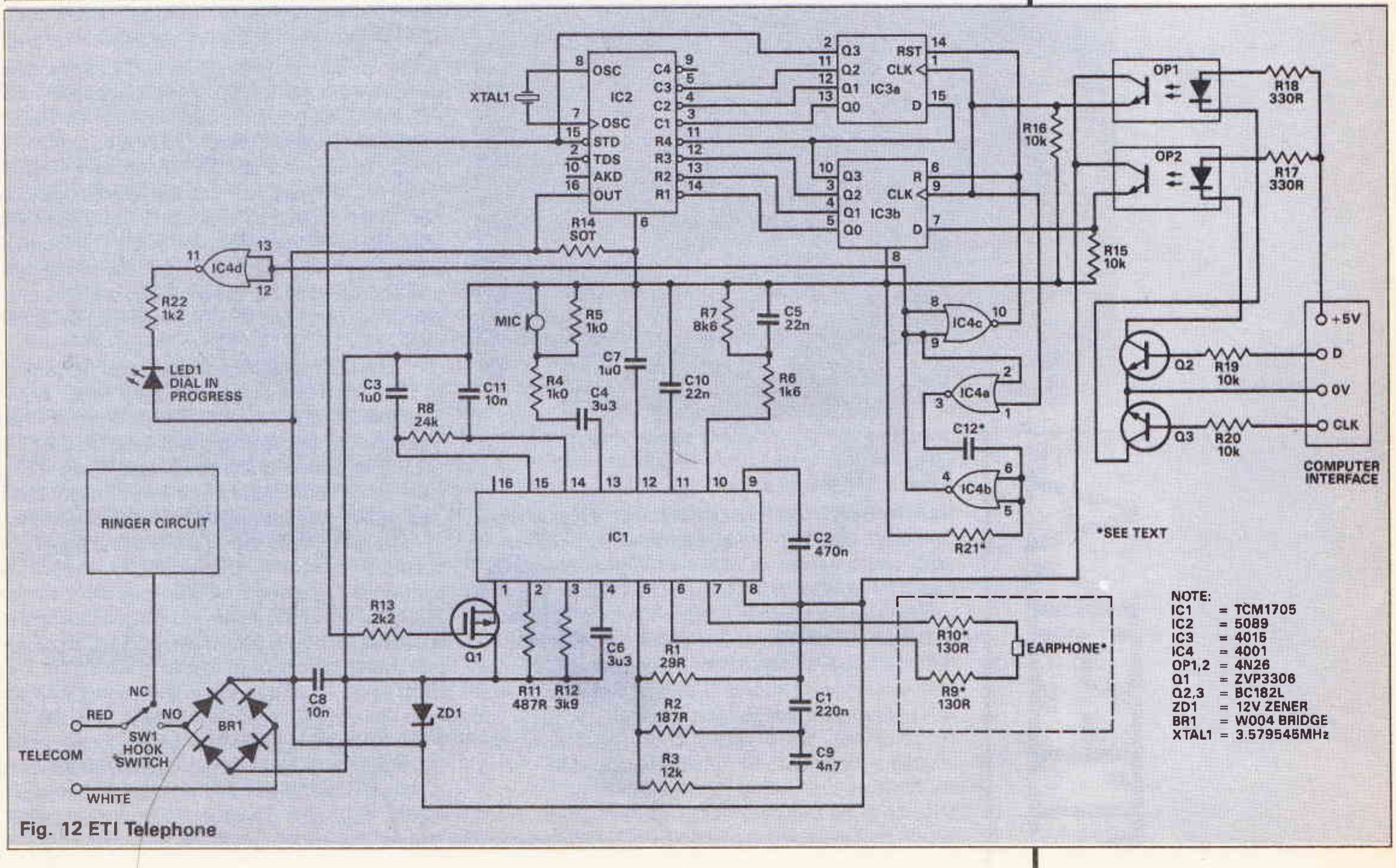


Fig. 12 ETI Telephone

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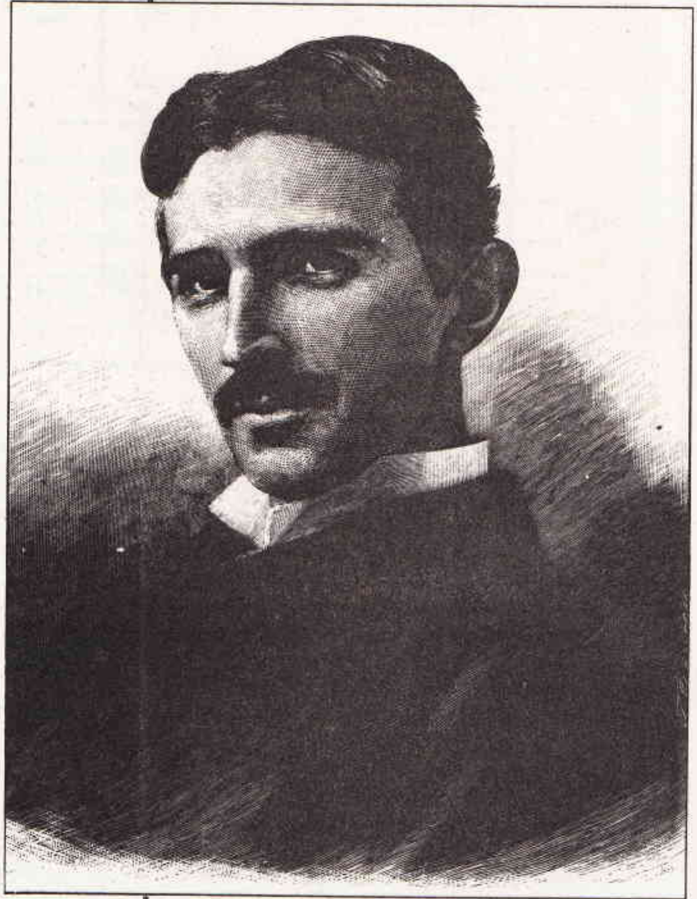
NIKOLA TESLA

The Man

In the first of two articles, George Pickworth introduces us to the brilliant eccentric who often failed to capitalise on his genius.

Born in 1856 in Smiljan, Croatia, Tesla paved the way for many of the technological developments of modern times. He is most widely remembered as the inventor of the Tesla Coil and for winning the titanic struggle between Edison's direct current electric power system and the Tesla-Westinghouse polyphase alternating current system. In 1917 Tesla was awarded the Edison Medal, the highest honour that the American Institute of Electrical Engineers could bestow and in 1956, his centennial year, the International Electrotechnical Commission named the unit of magnetic flux density the *tesla* (T) which was later adopted as part of the International System (S.I).



TESLA

DC versus AC

Early in the history of electrical power, it was realised that costs could be saved if generating plants were sited near coalfields or where water power was available. However, with the Edison DC systems, the only way to raise the voltage high enough for long distance transmission was to use low voltage motors to drive higher voltage dynamos (rotary converters). Similar converters were needed to reduce the voltage to a level suitable for distribution to users.

Not only were rotary converters expensive, requiring considerable maintenance, but arcing between the commutator sectors limited operation to about a thousand volts. Although AC transformers would be more elegant and less costly than rotary converters, at that time there were no industrial electric motors that would run on AC. In fact, Edison publicly announced that such a motor was an impossibility. Nonetheless, AC systems using transformers were used in the USA as early as 1880, but only for electric lighting.

While training for a career in electrical engineering at Graz Technical University in Austria, Tesla became involved with DC dynamos and motors. He conceived a way to run motors on AC using a simple slip ring system instead of troublesome commutators. Later, when studying at Budapest, Tesla visualised the principle of the rotating magnetic field and developed plans for an induction motor. This was the first step in the successful utilisation of AC power. However, it was not until Tesla was working for the Continental Edison Company in Paris, that he actually constructed, outside working hours, his first induction motor.

In 1884, Tesla arrived in New York with just four cents in his pocket, a few of his poems and calculation for a flying machine. He found employment with Thomas Edison, but the two inventors were so far apart in background and methods that their separation was inevitable. From that time, Tesla worked alone and continued to develop and patent his polyphase AC system. In May 1885, George Westinghouse, head of the Westinghouse Electric Company, bought the patent rights for Tesla's system of AC generators, transformers and motors. This transaction precipitated the huge power struggle between Edison and Tesla-Westinghouse.

Safety

Edison continued to promote his DC system, and to denigrate the AC system, spreading public fears that AC was dangerous. To allay these fears Tesla gave exhibitions featuring current flowing through his body to light lamps. Perhaps the most bizarre story is that when the Electric Chair was first approved for execution in the USA, AC was used, but it took several attempts to kill the unfortunate victim who was burnt first before being electrocuted. News of the incident was circulated in the mass media, and did much to convince the public that AC was actually safer than DC.

The first major demonstration of AC power was in 1893 when Westinghouse used Tesla's system to light the World's Columbian Exposition at Chicago. This success was an important factor in winning the contract to install the first power machinery in Niagara Falls, which bore Tesla's name and patent number. The project carried power to Buffalo by 1896.

Despite the many obvious advantages of high voltage AC power lines, if the length of the line equals a quarter wavelength at the operating frequency (1500km at 50HZ), it presents a high impedance and is useless for power transmission. A DC transmission line was therefore used to take power from Cabora Basa in Mozambique to Johannesburg and similar high voltage DC power lines are used in the USSR. Modern technology made brushless rotary converters a reality. Moreover, a high voltage DC system requires only two conductors, only one of which needs to be highly insulated. The other can be buried in the ground, significantly reducing the cost of the line.

In 1889, Tesla established his own laboratory at Colorado Springs where he experimented with shadowgraphs similar to those used later by Wilhelm Rontgen when he discovered X-rays. Tesla's countless other experiments included work on a carbon button lamp and various other kinds of lighting. Unfortunately, Tesla made no financial gain from many of his fundamental discoveries, most of which had no immediate practical use.

The Tesla Coil

From 1891 to 1893, Tesla gave lectures in Europe on high voltage, high frequency currents which he produced by means of a resonant transformer which he invented in 1891 and which came to be known as the Tesla coil. Essentially, a Tesla coil consists of a long helical coil, normally mounted vertically. A 'capacity hat', typically a large ball, is electrically connected to the upper end of the coil. The lower end of the coil is normally earthed. Capacitance between the turns, and the effect of the capacity hat, gives the coil a specific resonant frequency. When the coil is energised at that frequency, a high voltage develops between the hat and earth. The effect is analagous to the high voltage which occurs at the nodes of an Hertzian wave antenna, and demonstrated the need for high voltage insulators when the nodes of a wire antenna occur at the ends.

The traditional way to excite small Tesla coils (designed for experiments and demonstrations), was to use a spark system. Hertz had shown in 1888 that the discharge of a Leyden Jar (capacitor) across a spark gap was not simply a levelling of the potential between the two plates, but 'a continuous forward and backward surging' (oscillation) until a state of rest was achieved. Sustained oscillations could be maintained by having a continuous spark. The exciter was in effect a spark radio transmitter which could be tuned by using Leyden Jars and induction coils and was normally an integral part of the Tesla coil.

With low power Tesla coils and radio transmitters, a spark voltage of 20kV to 40kV was normally generated by vibrator type induction coils, but high powered spark transmitters often used 50kV to 100kV transformers using mains electricity or an engine driven alternator. The spark system was capable of generating considerable power, and 2.0kW for some of the shipboard installations was not unusual. The only limiting factor seems to have been physical constraints, particularly with regard to the spark gap and the insulation of the capacitors. However, Tesla excelled in finding solutions to these kinds of problems.

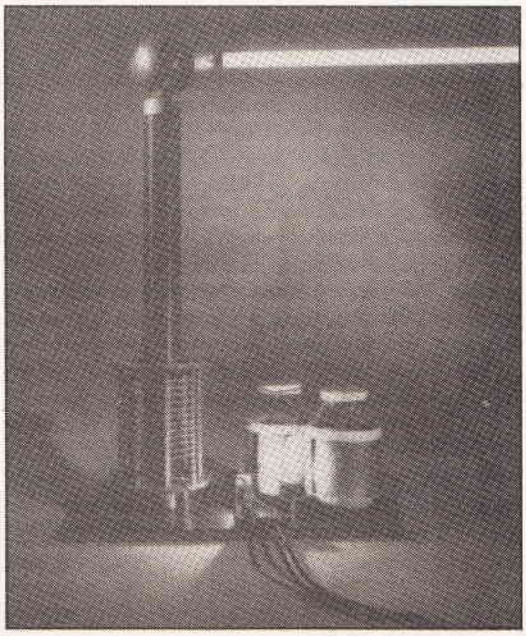
Spark radios and demonstration Tesla coils generally operated within the 0.5 to 3MHz range. With large coils it might have been difficult to obtain resonance at frequencies much above 3MHz, but there would have been few problems with resonance at frequencies of tens of kHz. As an alternative to the spark system it would therefore have been feasible for Tesla to excite very large coils by means of high frequency alternators: these devices were successfully used as radio transmitters before the First World War. Although the upper frequency limit for high power devices is generally considered to be about 20kHz, one machine was claimed to generate 'considerable power' at 100kHz (but this is doubted by the author).

Resonance

In 1889 at a gathering of the Royal Institute of Electrical Engineers, Tesla set out the essential elements of radio communications, covering antenna and ground circuits and most significantly, tuned receiving circuits. (Credit for successfully tuning the transmitter and receiver to the same frequency, *syntonization,* is attributed to Sir Oliver Lodge). Unfortunately, lack of commercial interest and arguments over technical points by those who had little understanding of Tesla's work prevented his scheme from being developed.

Tesla was fascinated by electrical resonance. In 1899 he announced what he called his most important discovery — 'terrestrial stationary waves'. He claimed that these proved that the Earth could be used as a conductor, which would be as responsive as a tuning fork to electrical vibrations of a certain frequency and this could 'split the earth like an apple'. At one time Tesla was convinced that he had received signals from another planet but this was greeted with derision by editors of scientific journals. Tesla was a godsend to reporters seeking sensational copy but was a problem for editors who were uncertain about how seriously to treat these reports.

Tesla believed that by using the principle of electrical resonance it was possible to transmit power over long distances without transmission lines. With this objective, he began to experiment with very large



Replica of original Tesla coil, lighting fluorescent tube.

Tesla coils in various configurations and installations, some of which were several hundred feet tall. By means of such large coils he was able to create 'lightning' with the discharge spanning more than 100 feet. However, the author is sceptical about Tesla's claims that power could be transmitted over long distances without transmission lines, despite contempory accounts of 200 lamps being lit by power radiated from a large installation at a distance of 25 miles. The manner in which the power would be transmitted is obscure.

The 'capacity hat' of a Tesla coil produces a strong electric field while the actual coil creates a strong magnetic field. Even with a small demonstration coil these fields will light up a flourescent tube held near the coil, and Geissler tubes, the forerunners of flourescent tubes, were available to Tesla. By the same token the magnetic field of a large Tesla coil may well have lit up incandescent lamps connected to resonant induction coil a short distance away. This effect can be observed today with a suitable device placed fairly close to a powerful broadcasting station, but readers are warned against doing this.

World-Wide Broadcasting

Returning to New York in 1900, Tesla began to construct what he called a 'world-wide broadcasting tower' on Long Island. This was done with $150,000 capital put up by the financier Pierpoint Morgan. The object

TESLA

was to transmit news reports, stock reports, pictures and weather warnings on a world-wide basis. Tesla's tower would presumably have incorporated features described by him during his 1892 lectures on radio communication. However, because of labour problems and a financial panic, Morgan withdrew his support and the project was abandoned. It was Tesla's greatest defeat. If the tower had been successfully completed and had been found to work it would have predated the British Empire VLF Communication Transmitter at Rubgy by 35 years.

It would be pure speculation to suggest that Tesla planned to operate a VLF world broadcasting tower or that alternators were to be used: large spark devices would have been just as applicable. Nonetheless, these frequencies were within the limits of high power high frequency alternators, and a fascinating feature of the project is that in 1900, no-one, with the possible exception of Tesla, conceived that frequencies between 10 and 20kHz (VLF) were ideally suited for reliable global communication. Moreover, as already explained, high frequency alternators were successfully used as radio transmitters before WW1. Indeed a superheterodyne receiver using a alternator as the local oscillator was the most sensitive receiver available and mixing took place in the headphones.

In December 1901, Marconi successfully transmitted and received transatlantic signals, demonstrating that Hertzian waves are able to follow the curvature of the earth.

The main problem with VLF communication is the efficient conversion of high frequency electric currents into Hertzian waves. Apparently, this is only possible when the current flows linearly along a conductor. So unless Tesla had discovered an alternative method of coupling his coils to the 'ether', extremely long antennae would be required. Marconi exploited Hertzian waves using a spark transmitter. By operating on a frequency of around 1.0MHz, efficient radiation of Hertzian waves was possible with an antenna of practical size.

With the abandonment of the 'world broadcasting' project, Tesla directed his attention to turbines and many other projects, but because of shortage of funds, his ideas remained as notes which are still studied by engineers for unexploited ideas. In 1915 Tesla applied for an injunction against Marconi, but this was denied largely because there were few who understood the significance of his work. A review of this decision in 1943 held that Marconi's patents were invalid because they had been anticipated by Tesla.

After his death, the custodian of alien property impounded his papers, laboratory notes, letters, and honours: these were eventually inherited by his nephew and later housed in the Nikola Tesla Museum in Belgrade. However, stories are rife that many of his notes were destroyed because his discoveries were too dangerous to be made public. These were fuelled by Tesla's claims that he had invented a death ray and that the earth could be split like an apple.

ETI

Further reading:

Inez Hunt and Wanetta W Draper: *Lightning in his hand: The life story of Nikola Tesla (1964)*.

Nikola Tesla Museum: *Nikola Tesla: Lectures patents articles (1956)*.

Nikola Tesla Museum: *Experiments with alternate currents of high potential and high frequency (1904)*.

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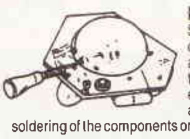

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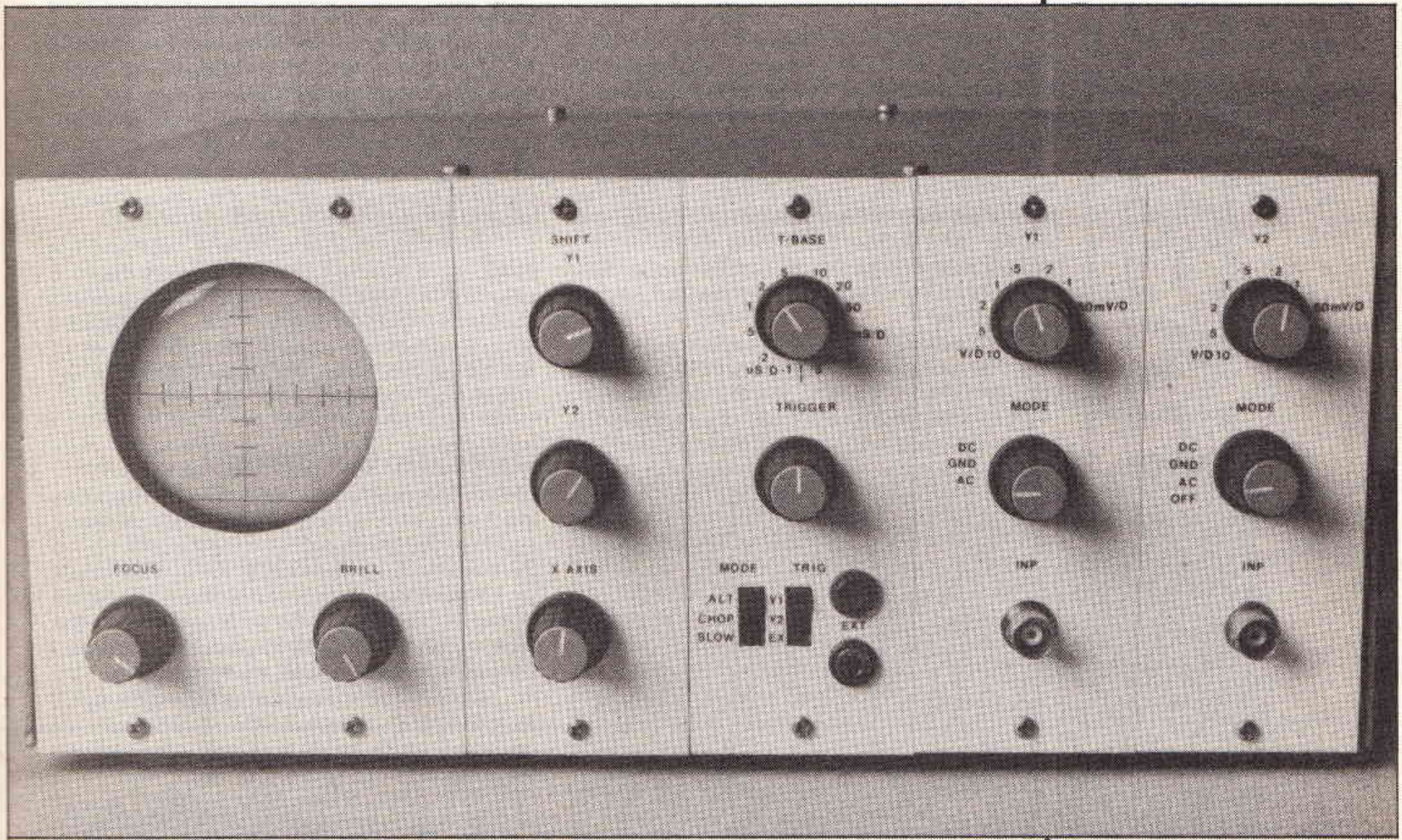
SUPERSCOPE REVISITED



In response to popular demand, Dennis Stanfield follows up his Superscope project with some instructions how to use it!

This follow-up to the Superscope project published in ETI this February and March should give beginners an insight into how an oscilloscope works in general and how to get the best out of the Superscope in particular.

We initially thought that anyone who felt competent enough to construct such a complex project would have enough knowledge and expertise to make an overview of procedures unnecessary. However the project has proved attractive to many beginners in electronics and we have had many queries and requests for further details.

Clearing Up Some Queries

Lets get a few points out of the way first.

There were a few errors and omissions in the original articles. Those we have found are listed in the Oops! column in this issue.

A number of readers have asked for details of front panel layout. This is shown in the above photograph. A front panel is now available from the ETI Front Panel Service.

We have been asked why not use a more modern tube as these generally have a brighter sharper trace. There are two reasons.

Firstly, to obtain a brighter trace much higher HT voltages are required, of the order of several thousand volts for most post-deflection-anodes. The generation of such voltages with the associated safety considerations is unsuitable for all but the most competent. The fact that so many novice constructors have been attracted to this project reinforces this view; we wouldn't want to lose any of you.

Secondly, more modern tubes are generally about two or three times the price of the 'surplus' type tubes recommended, defeating the low-cost attraction of this project.

If you wish to experiment, the design of the unit lends itself readily to adaptation. In view of the hand wound transformer it would not be wise to try to generate too high an AC voltage from the transformer. Increasing the voltage by chaining multiplier PDA requires virtually no current. However, you are on your own. Please do take care with these very high tension voltages, *they are lethal.*

Oscilloscope Basics

Those of you who are familiar with oscilloscope techniques can skip this bit. For those who are not, this is necessarily a brief resumé of the basics of oscilloscope operation.

The 'scope is the most useful tool available to the electronics technician for testing equipment. It is capable of performing a wide range of measuring functions (such as voltages, and frequencies directly, and other parameters indirectly) and provides a real-time visual display of what is actually happening to a signal in the circuit. How is this achieved?

All the circuitry within a 'scope has the sole purpose of moving a bright spot horizontally or vertically across the face of the cathode ray tube (CTR) under the control of the timebase (X-axis) and the input signal (Y-axis).

Consider first the X-axis. If the spot races across the tube face fast enough the eye sees a horizontal line or *trace* rather than a moving spot. If, when the trace reaches the right-hand side of the tube face, we cause it to *fly back* the left-hand side even faster still and repeat the process, a seemingly static horizontal line is maintained across the screen. If the control of the Y-axis is now varied at a suitable rate by an input signal, those variations will be superimposed on the trace causing vertical deflections in it as dictated by the input signal.

A cathode ray tube (see Fig.1) is in effect a very large thermionic valve. However the stream of electrons emitted from the hot cathode, instead of being attracted to the anode and allowing current flow as in a normal valve, is actually guided and focussed by several anodes to produce a narrow beam. When these hit the phosphorescent material on the inside face of the tube, it phosphoresces at the point of impact. The voltages applied to the anodes must be progressively more positive to ensure attraction of the electrons into a stream and their focussing into a narrow beam.

The moving of the beam is performed by the X and Y plates which are arranged in two symmetrical pairs (see Fig 1). These plates are also positively charged. When the charge on each plate of a pair is identical the beam passes straight down the middle between them and hits the centre of the screen (manufacturing tolerances aside). But if there is an imbalance, with one plate more positive than the other, the electron beam is bent towards the more positive plate by electrostatic attraction. This causes the spot to move up, down or across the tube depending on which plate is the more positive. The reverse effect is caused by making one plate more negative with respect to its partner.

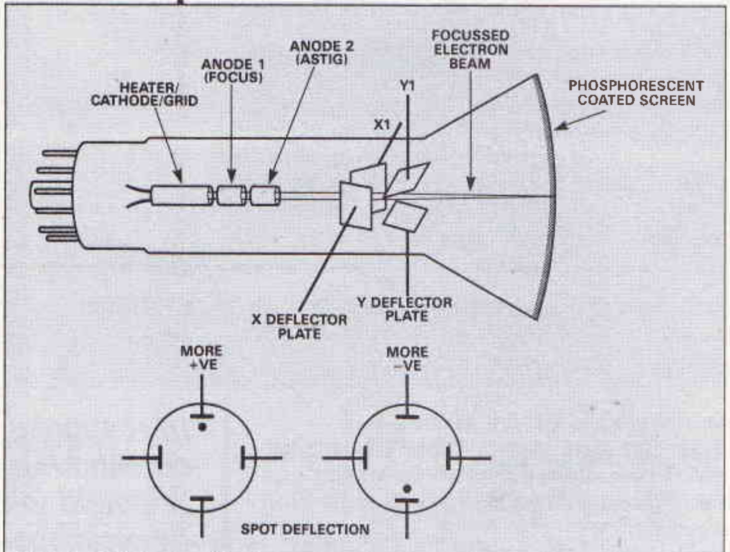


Fig. 1. Oscilloscope Basics

While a workable 'scope could be made by holding one plate of each pair at a constant voltage and varying the potential in the other, this causes non-linearity in the spot deflection because of the variations in the strength of the electrostatic field. Instead, the plates are driven in anti-phase so that as one becomes more positive the other becomes more negative with respect to their quiescent mean charge. This also has the advantage of requiring a reduced driver voltage as the voltage swing is effectively doubled.

The rate at which the spot moves horizontally across the screen is controlled by the period of the sawtooth waveform applied to the X driver by the time base. Although on the Superscope the timebase drive to the X amp is unbalanced, the action of the differential output stage produces a balanced output to the tube, the collector voltage of one of the output transistors (and hence the plate voltage) rising as the other falls and vice-versa.

In contrast the Y amp is driven by a balanced input requiring a lesser voltage swing to drive each transistor, the sum of the two input voltages (in antiphase) times the gain giving the required output voltage swing.

Now we've got various signal traces marching across the screen, how do we make some sort of an intelligible display out of this rubbish? The answer is to trigger the sawtooth (ramp) generator to start its ramp cycle at a particular point on each repetition, (or set of repetitions) of the input waveform. Each trace is identical to the one which preceded it and a steady, viewable trace is built up on the screen. The trigger point is selected by adjustment of the variable trigger control.

What happens during the time that the spot is flying back to the start point? Is the trace drawn in reverse? No, the flyback is made to happen as fast as possible. It would be barely visible, but a negative going blanking pulse is sent to the CRT grid, cutting off the electron beam and rendering the flyback completely invisible.

Using The Superscope

First and foremost let me make it clear that this project is not suitable, *under any circumstances,* for testing equipment whose chassis is live to the mains; such as the majority of television sets in use in this country.

It is assumed that you have followed the set-up procedures described in the second article and that you are in possession of a fully operational 'scope and are now wondering what to do with it.

Whilst not as bomb-proof as older valve-based input amplifiers, those in the Superscope are reasonably robust. Inputs from most semiconductor based circuitry are unlikely to cause damage at virtually any input attenuator setting within reason. Unless you are displaying a very low frequency signal or a DC input mode selectors should be set to AC. This removes any DC offset from the input and avoids the trace being moved about (or off) the screen when switching between attenuation ranges.

• Displaying A Trace

Input a signal into either of the Y channel inputs and switch the trigger select to that channel. Set the timebase to a range which will allow 5-10 cycles of the waveform to be displayed. Adjust the trigger control to stabilise the trace. You may find that at certain input frequencies the arrival of the retrigger point occurs just as the trigger flip-flop reset pulse is ending. This may lead to some jitter in the display. Moving up or down one timebase range will cure this problem.

A better solution would have been to allow some front panel fine adjustment of the ramp period but unfortunately space is at a premium, especially on the timebase front panel. As the problem is an infrequent one however, a compromise was acceptable. If you want to make a modification to include fine tuning of the ramp period (and can find space for it) you could break the connection between RV302 and R304 and connect a very low valve potentiometer of up to about 470 ohms between the two flying leads. (One lead will go to one end of the potentiometer track and the other lead to the wiper). When calibrating the timebase do so with the wiper of the new pot at one end or other of its track and mark that setting 'CAL'. This is common to most 'scopes and explains the timebase fine adjustment found on many.

• Dual Trace Mode

In dual trace mode you have the choice of chopping each trace into two or tracing each input on alternate

TEST GEAR

traces. The former, which is really only useful at audio frequency inputs, causes the beam to draw a minute part of Y1 trace followed by a similarly minute part of the Y2 trace, and so on across the screen. As ramp speed is increased the discrete bits of each trace become separate and the display takes on the appearance of a pair of dashed lines across the screen. Chopped mode does ensure simultaneous channel displays whereas in alternate mode one of other trace is always out of date by one ramp period (not that that causes any difficulty in most cases). In normal use alternate mode is usually left switched in. At very slow timebase ranges the dual traces would actually be seen to alternate so chopped mode is enabled automatically.

With inputs to both Y channels a stable trace for each will only be achieved if their frequencies are identical or harmonically related. With unrelated frequencies one channel (the trigger channel) will lock and the other will run through at a rate dependant upon their dissimilarity. Dual mode is useful for example for comparing the output of a circuit to its input signal. Distortions, phase shifts and so on, may be detected in this way. It must be noted that above about 5MHz square waves will begin to be reshaped as the high level harmonics of the fundamental come up against the end-stops of the deflection amplifier's gain and slew rate capabilities.

- **Taking Measurements**

Frequency measurements may be made using the formula 1/T where T is the time taken for one whole signal cycle as measured off the display. For example if the timebase setting is 1µs/Div and each cycle takes 2.5 divisions, then the frequency is:

$$\frac{1}{2.5\times10^{-6}} = 400\text{kHz}$$

Voltage measurements may be read directly making due allowance for reduction in gain for the increased frequencies as set out in specifications in ETI February 90. Remember that you will be reading peak-to-peak values of AC signals. DC measurements are made by switching the input mode selector to ground and, with relevant Y shift, setting the trace to the datum line. If the mode selector is then moved to DC and the input applied, the deflection of the trace times the input attenuator setting gives the voltage. The direction of movement gives the polarity: positive is up and negative is down.

Current and resistance measurements are indirectly possible by the thoughtful application of that ever faithful friend Ohm's Law. For example, by displaying the voltage produced by an unknown current through a known resistor or by a known current through an unknown resistor.

As with all oscilloscopes (apart from some of the very high tech laboratory types) the accuracy of measurement is not as good with a dedicated frequency or volt-meter. However, it is more than adequate for workshop purposes and those meters cannot show you pretty pictures of the actual signal. A typical £400-£500 commercial 'scope will have an accuracy of about ±3% or so. Careful calibration of the Superscope should give an accuracy within at least shouting distance of that.

One could write a book about the many and varied uses to which an oscilloscope can be put and in fact a number of authors have. ETI's current 'Testing Testing' series contains much useful and relevant information and is recommended for further reading.

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1

MODERN DIODE CIRCUITS

Ray Marston starts a new series exploring the functions of diode circuits, with a general look at diodes and their applications.

The solid-state diode is the most fundamental element used in modern electronics, and is available in a variety of forms, including those of signal detector, rectifier, zener (voltage reference) diode, noise-generator diode, varicap (variable capacitance) diode, light-sensitive diode (photodiode), and light-emitting diode (LED). In the first part of this series we'll look at the basic characteristics of diodes and then show a variety of ways of using standard diodes and rectifiers.

Basic Diode Characteristics

The solid-state diode is a two-terminal device that passes current easily in one direction, but blocks it in the other. Figure 1 shows (a) the conventional symbol and (b) the basic structure of the modern solid-state 'junction' diode. The diode is formed from a single p-n junction. The *p* terminal is known as the *anode* and the *n* terminal as the *cathode*.

Fig 1. (a) Symbol and (b) structure of solid-state diode.

Figure 2 illustrates the basic characteristic of the diode. When it is forward biased (with the anode positive relative to the cathode), the diode acts like a low resistance and readily passes current, but when it is reverse biased (with the anode negative relative to the cathode) it acts like a high resistance and passes near-zero current. This action is implied by the basic diode symbol, which resembles an arrow pointing in the direction of easy current conduction.

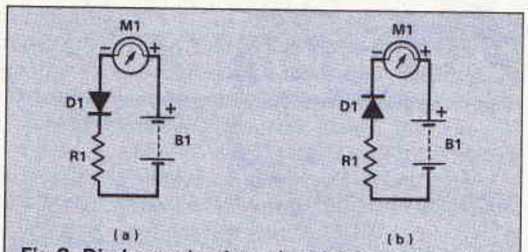


Fig 2. Diode conduction when (a) forward and (b) reversed biased.

Conventional junction diodes are made from either germanium or silicon. Figure 3 compares the basic characteristics of the two types of device when operated at a nominal room temperature of 20°C. Note the following important points.

1. A forward biased junction diode passes little forward current (I_f) until the applied forward voltage (V_f) exceeds a certain 'knee' value (typically 150 to 200 mV in germanium diodes, 550 to 600 mV in silicon types). When a diode is operated beyond its knee value, small increase in V_f cause large increase in I_f. The device's forward dynamic impedance (Z_f) is inversely proportional to applied voltage.
2. The Z_f of a silicon diode has a typical value (in ohms) of 25/I, where I is measured in mA; so Z_f = 25R at 1mA, 2.5R at 10mA, and 0.25R at 100mA. The Z_f of a germanium diode is greater than that of a silicon type; consequently its V_f usually exceeds that of silicon type at I_f values greater that a few tens of mA.

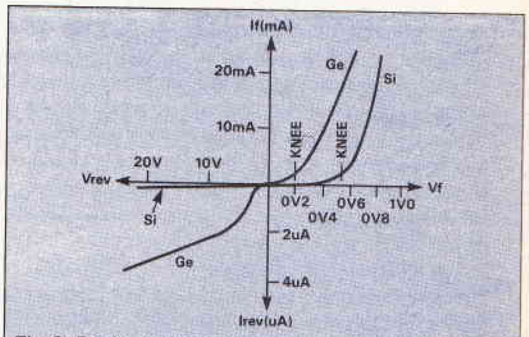


Fig 3. Basic characteristics of germanuim (Ge) and silicon (Si) junction diodes (at 20°C).

3. When a diode is reverse biased by more than one volt or so it passes a reverse leakage current (I_r) that is almost directly proportional to the reverse voltage (V_r) value. At normal room temperatures I_r values are measured in microamps in germanium devices and in nanoamps in silicon devices. I_r is highly temperature dependent, and typically doubles for each 8°C increase in junction temperature.

Because of their low knee voltage values, germanium diodes are used almost exclusively in low-level *signal detection* applications. The great majority of junction diodes are silicon types, and can be used in many general-purpose applications. Diodes that have high reverse voltage and forward current ratings are usually called *rectifiers*.

Special Diode Characteristics

Ordinary silicon diodes have several special characteristics in addition to those we have already looked at. The most important of these are illustrated in Figures 4 to 7.

If a silicon diode is increasingly reverse-biased it eventually reaches a point where the reverse current suddenly starts to increase. Any further increase in V_r causes a sharp rise in I_r, as shown in Figure 4. The voltage at which this action occurs is known as the avalanche or *zener* value of the device, and is sharply defined. Some silicon diodes are specially manufactured to exploit the zener effect, and can be used

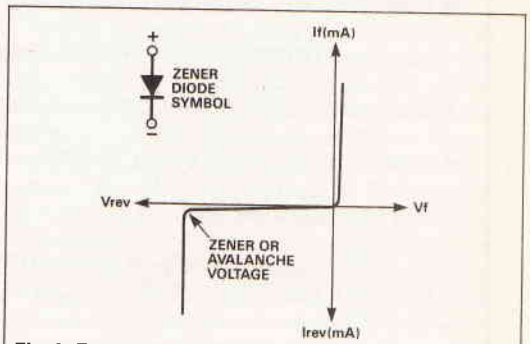


Fig 4. Zener diode symbol and characteristics.

CIRCUITS

as *reference voltage* generators. Such devices are depicted by the circuit symbol shownin the diagram.

All zener diodes have impedances that inherently fluctuate in a rapid and random manner, and so can be used as excellent white-noise sources.

If a silicon diode is forward biased via a constant-current generator, its V_f value varies with junction temperature at a rate of $-2mV/°C$, as shown in Figure 5, so if $V_f = 600mV$ at $+20°C$, it falls to 440mV at 100°C or rises to 740mV at $-50°C$. Silicon diodes can be used in this way as temperature-to-voltage converters.

If a silicon diode is reverse biased from a high-impedance source (as shown in Figure 6) its junction

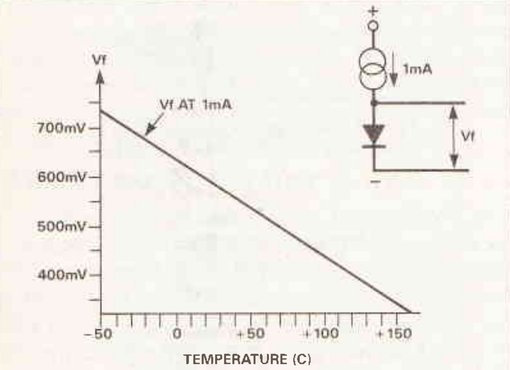


Fig 5. Thermal characteristics of a silicon diode at $I_f = 1mA$.

capacitance will decrease (from perhaps 17pF at $-1V$ to maybe 10pF at $-8V$) as the reverse bias is increased. Some silicon diodes are specially manufactured to exploit this voltage-variable-capacitor effect. They are known as *varicap* or *Varactor* diodes, and are depicted by the circuit symbol shown in Figure 6.

When p-n junctions are reverse biased, their leakage currents and impedances are inherently opto-sensitive. They act as very high impedances under dark conditions and as low impedances under bright ones. Normal diodes have their junctions shrouded in opaque material to stop this unwanted effect, but some are specially manufactured to exploit it. These are called photodiodes, and use the symbol shown in Figure 7a. Some of these photodiodes are designed to respond to visible light, and some to infra-red (IR) light.

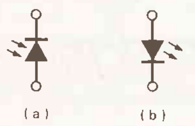


Fig 7. Symbols for (a) photodiode and (b) LED.

in Figure 7b.

Finally, one other important type of p-n junction device is the Schottky diode. These devices use the standard diode symbol, but offer a very fast switching action and develop forward voltages that are almost half as great as conventional silicon diodes. They can be used to replace germanium diodes in many signal detector applications, and can operate at frequencies up to tens or hundreds of GHz.

Half-wave Rectifier Circuits

The simplest application of the diode is as a half-wave rectifier. Figure 8 shows a transformer-driven circuit of this type (with the diode's input voltage V_{in} specified in volts rms) together with relevant output waveforms. If this circuit is used with a purely capacitive load it acts as a peak voltage detector and the output (V_{pk}) equals $1.41 \times V_{in}$, but if used with a purely resistive load it acts as a simple rectifier and gives an rms output of $0.5 \times V_{in}$. If it is used with a resistively-loaded capacitive load (as in simple power

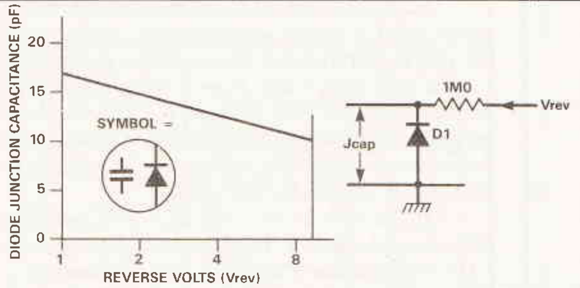


Fig 6. Varactor (varicap) diode symbol and typical characteristics.

supply applications) the output is *rippled* and has an rms value somewhere between these two extremes. In capacitively-loaded circuits the diode needs a peak reverse-voltage rating of at least $2.82 \times V_{in}$; if purely resistive loading is used the rating can be reduced to $1.41 \times V_{in}$.

If this circuit is used to power purely resistive loads they will consume only a quarter of maximum power, since power is proportional to the square of applied rms voltage. However, very few loads are purely resistive, and Figures 9 to 11 show how the basic half-wave rectifier circuit can be adapted to give 2-level power control of lamps, electric drills, and soldering irons that are operated from the AC power lines. In each of these circuits the rms voltage fed to the load equals V_{in} when S_1 is in position 3, or $0.5 \times V_{in}$ when S_1 is in position 2.

The Figure 9 circuit uses a lamp load, which has a resistance roughly proportional to its filament temperature. When it is operated at half the maximum voltage its resistance is only half the maximum, so the lamp operates at about half maximum power and

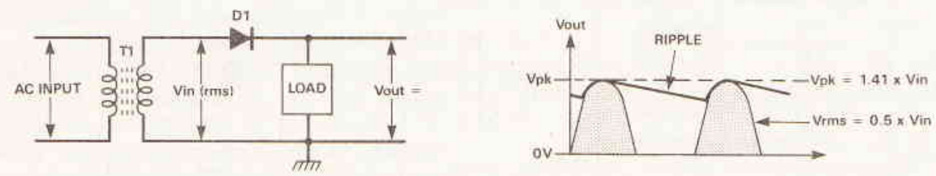


Fig 8. Circuit and waveforms of transformer driven half-wave rectifier.

Another useful type of junction diode device is the LED, or light emitting diode, which is made from materials such as gallium phosphide or gallium arsenide and which may be designed to emit either red, green, yellow or infra-red light when suitably forward biased. These devices use the symbol shown

burns at half-brilliance with S_1 in the DIM position.

The Figure 10 circuit uses the universal motor of an electric drill as its load. Such motors have an inherent self-regulating speed control capacity, and because of this the motor operates (when lightly loaded) at about 70% of maximum speed when S_1, is in the PART position.

The Figure 11 circuit uses a soldering iron heating element as its load, and these have a resistance that increases moderately with temperature. When the iron is operated at half voltage its resistance is slightly reduced, so the iron operates at about one third of maximum power when S_1 is in the SIMMER position. This keeps the iron heated but not to such a degree that its bit deteriorates.

Note that in all these circuits D_1 can be any type that has a current rating matched to the load requirement and with a peak reverse-voltage rating of at least $1.41 \times V_{in}$.

Full-wave Rectifier Circuits

Figure 12 shows how four diodes can be connected in the form of a bridge and used to provide full-wave rectification from a single-ended input signal. The output waveform of this circuit has twice the frequency of the input, so this circuit can also be used as a simple frequency doubler.

The best known application of full-wave rectification is in DC power supply circuits, which provide DC power outputs from AC power line inputs. These consist of a little more than a transformer which converts the AC line voltage into an electrically isolated and more useful AC value, and a rectifier-filter combination that converts this new AC voltage into smooth DC of the desired voltage.

Figures 13 to 16 show the four most useful basic power supply circuits. The Figure 13 circuit provides a DC supply from a single-ended transformer and bridge rectifier combination, and gives a performance virtually identical to that of the centre-tapped

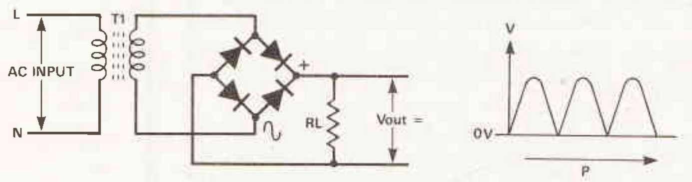


Fig 12. Bridge rectifier/frequency-doubler circuit.

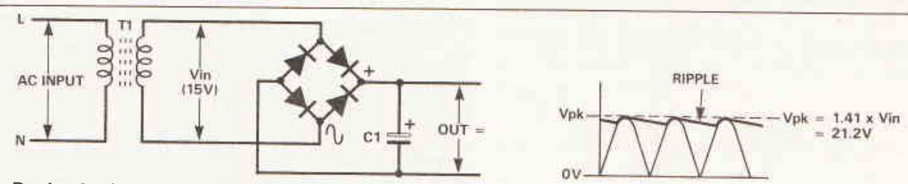


Fig 13. Basic single-ended PSU using bridge rectifier.

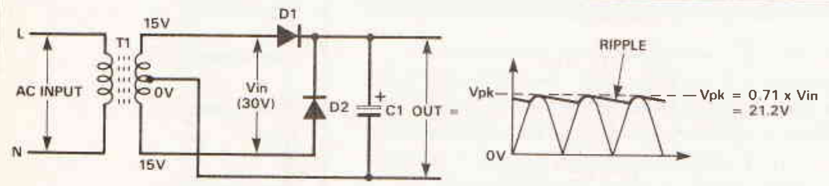


Fig 14. Basic single-ended PSU using centre-tapped transformer.

transformer circuit Figure 14. The Figure 15 and 16 circuits each provide split or dual DC supplies with nearly identical performances. The rules for designing these circuits are quite simple and we'll look at these rules next.

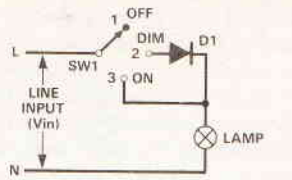


Fig 9. Lamp burns at half brightness in DIM position.

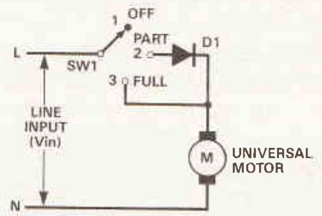


Fig 10. Drill motor runs at 70% of maximum speed in PART position.

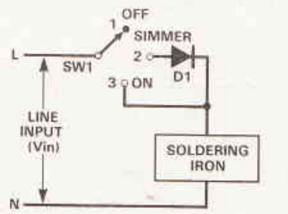


Fig 11. Soldering iron operates at ⅓ power in SIMMER position.

Transformer Rectifier Selection

The three most important parameters of a transformer are its secondary voltage, its power rating, and its regulation factor. The secondary voltage is always quoted in rms terms at full rated power load, and the power load is quoted in terms of volt-amps or watts. Thus, a 15V 20VA transformer gives a secondary voltage of 15V rms when its output is loaded by 20V. When the load is removed (reduced to zero) the secondary voltage rises by an amount implied by the regulation factor. So the output of a 15V transformer with a 10% regulation factor (a typical value) rises to 16.5V when the output is unloaded.

The rms output voltage of the transformer secondary is *not* the same as the DC output voltage of the complete full-wave rectified power supply. As shown in Figure 17, the DC output is in fact 1.41 times greater than that of a single-ended transformer, or 0.71 times that of a centre-tapped transformer (ignoring rectifier losses). Thus, a single-ended 15V rms transformer with 10% regulation gives an output of about 21 volts at full rated load (just under 1A at 20VA rating) and 23.1V at zero load. When rectifier losses are taken into account the output voltages will be slightly lower than shown in the graph. In the *two-rectifier* circuits of Figures 14 and 16 the losses are about 0.6V and in the *bridge* circuits of Figures 13 and 15 they are about 1.2V. For maximum safety, the rectifiers should have current ratings at least equal to

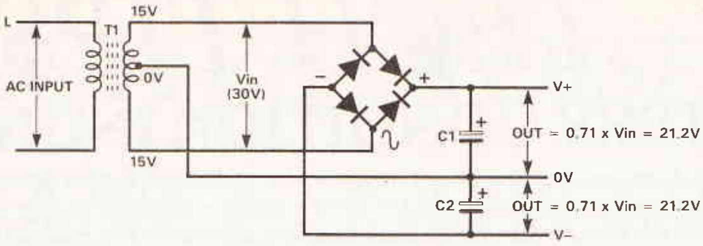


Fig 15. Dual (split) PSU using centre-tapped transformer and bridge rectifiers.

the DC output currents.

So the procedure for selecting a transformer for a particular task is quite simple. First, decide the DC output voltage and current that you need; the product of these values gives the minimum VA rating of the transformer. Then consult the graph of Figure 17 to find the transformer secondary rms voltage that corresponds to the required DC voltage.

The Filter Capacitor

The filter capacitor converts the full-wave output of the rectifier into a smooth DC output voltage. The two most important parameters are its working voltage, which must be greater than the off-load output value of the power supply, and its capacitance value, which determines the amount of ripple that will appear on the DC output when current is drawn from the circuit.

As a rule of thumb, in a full-wave rectified power supply operating from a 50 — 60 Hz power line, and output load current of 100mA, will cause a ripple waveform of about 700mV peak-to-peak to be developed on a 1000µF filter capacitor. The amount of ripple is directly proportional to the load current and inversely proportional to the capacitance value, as shown in the design guide of Figure 18. In most practical applications, the ripple should be kept below 1.5V peak-to-peak under full load conditions. If the ripple must be very small, the basic power supply can be used to feed a 3-terminal voltage regulator IC, which can easily reduce the ripple by a factor of 60dB or so at low cost.

Rectifier Ratings

Figure 19 summarises the characteristics of the three basic types of rectifier circuit and gives the minimum PIV (peak inverse voltage) and current ratings of the individual rectifiers. The full-wave circuit (using a centre-tapped transformer) and the bridge circuit (using a single-ended transformer) each give a typical full-load output voltage of about 1.2 × E and need diodes with minimum current ratings of 0.5 × I (where I is the load current value), but the bridge circuit's PIV requirement is only half as great as that of the full wave circuit.

In the next part of this series, we will look at voltage multipliers, clamps and logic networks.

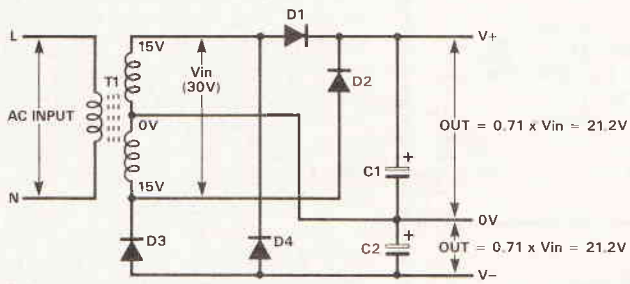


Fig 16. Dual (split) PSU using centre-tapped transformer and four rectifiers.

CIRCUIT	Vin (rms)	NO-LOAD OUTPUT	FULL-LOAD OUTPUT	RECTIFIER RATINGS	
				PIV	CURRENT
HALF WAVE	E	1.41 x E	E	2.82 x E	I
FULLWAVE	E+E	1.41 x E	1.2 x E	2.82 x E	0.5 x I
BRIDGE	E	1.41 x E	1.2 x E	1.41 x E	0.5 x I

Fig 19. Rectifier circuit characteristics.

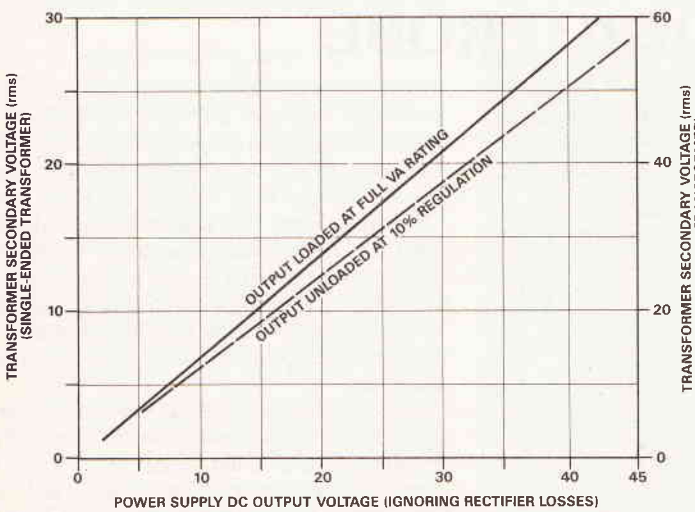


Fig 17. Transformer selection chart. Decide on the required loaded DC output voltage (say 21 volts), then read across to find the corresponding secondary voltage (15V single-ended or 30V centre-tapped).

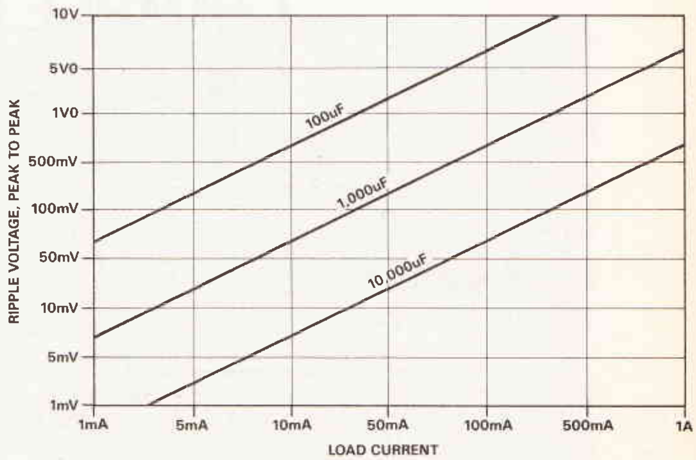
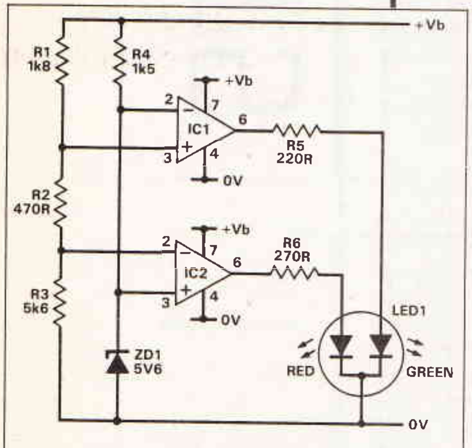


Fig 18. Filter capacitor selection chart, relating capacitor size to ripple voltage and load current in a full-wave rectified 50-60Hz powered circuit.

TECH TIPS

BATTERY CONDITION INDICATOR

This device indicates the state of charge of a battery by the colour of a dual LED. The LED can serve both as a battery indicator and as a power indicator light for battery/mains equipment. The circuit is primarily intended for small portable battery powered instruments that are seldom switched on for hours on end but are only occasionally used. In this application the power consumed by the circuit is less important than the need to avoid inaccurate readings that would result from a weak battery.



NOTE:
IC1,2 = 741
ZD1 = 5V6 400mW
LED1 = RED/GREEN COMMON CATHODE

Vb REFERS TO A 9V BATTERY VOLTAGE
Vb < 7V3 LED1 IS RED
Vb > 7V3 AND Vb < 8V0 LED1 IS YELLOW
Vb > 8V0 LED1 IS GREEN

The complete circuit diagram is shown here. Component values are those calculated for a 9V battery supply. The reference voltage across ZD1 is applied to the inverting input of IC1 and the non-inverting input of IC2, both of which are wired as voltage comparators. With a supply exceeding 8V the pin 3 potential of IC1 is higher than the reference voltage and the green LED is lit. The pin 2 potential of IC2 will also be higher than the reference and therefore the red LED will be off. As the supply voltage falls, these potentials gradually move toward the reference voltage. Resistor R2 produces an overlap in the response of the voltage comparators to the falling supply voltage. First, IC2 output changes state and the red LED is lit. This results in a yellow light which indicates a middle aged battery. A further fall in the supply voltage to 7.3V causes IC1 output to change state and the green LED is extinguished leaving only the red, which indicates that the battery needs replacing.

The response of this circuit to the falling supply is that after a of approximately 10% the LED goes from green to yellow, and goes from yellow to red after a further 10% drop.

The difference in the values of current limiting resistors R5 and R6 allows for the slightly larger forward voltage drop across the green LED.

In order to make a first approximation of the component values component tolerances can be ignored.

Note that the red light is extinguished at a high supply voltage (E_h) and the green one is switched off at a lower supply voltage (E_l). Note also that the voltage across R3 will be equal to the reference voltage (E_r) at the point where the red LED is about to make a transition. If 1mA is allowed through R3 under these conditions then the value of R3 will be E_r kilohms.

Now the same current of 1mA must flow through R1 and R2 also. Therefore R1+R2+R3 = E_h kilohms. Let this total resistance value = R_t.

When the supply potential drops to E_l, the reference voltage E_r appears at the junction of R1 and R2. Now the current (I) flowing through the resistors is E_l/R_t.

The voltage drop across R1 is E_l-E_r and therefore the current through R1 is $(E_l-E_r)/R1$. But this is the same current as I above. Consequently:

$$E_l/R_t = (E_l-E_r)/R1$$

therefore:

$$R1 = R_t(E_l-E_r)/E_l$$

and also since the value of R3 is known then;

$$R2 = R_t-(R1+R3)$$

Component tolerances can give results that differ somewhat from those calculated, particularly the value of R2. The best method of construction is to breadboard the circuit first and make any adjustments to the component values by trial and error before final assembly.

A design for a lower voltage indicator would require a smaller reference diode in order to keep the op-amp input levels away from the supply potentials.

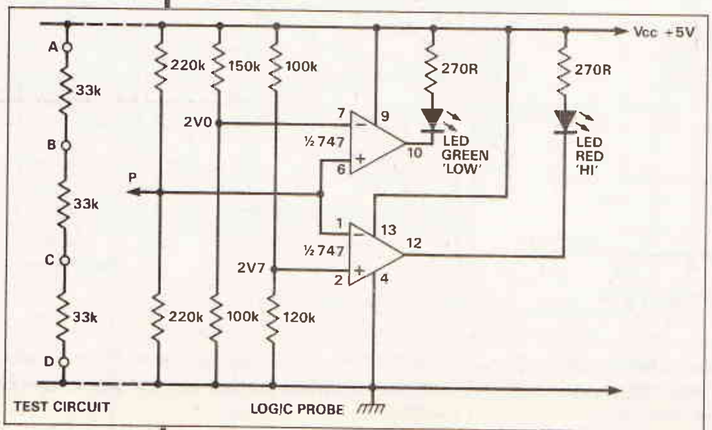
The individual LED currents are between 13mA and 15mA. Attempts to take more will cause the op-amp output voltage to drop. Typical 741 output voltages at this level of current consumption are approximately 3V lower than the supply voltage.

Note that the circuit can be built using either two op-amps, or alternatively a 1458 dual 741 may be used for a more compact circuit board.

A S Hughes,
Holywell, Clwyd.

SIMPLE LOGIC PROBE

It takes only one integrated circuit, two LEDs and few resistors to implement this logic probe. The probe was designed to provide basic two level tests. The circuit uses a 747 dual op-amp, as shown below.



The reference levels are adjusted such that there is no output between 2V and 2.7V, and both LEDs are off. If the input to the probe at point P is below 2V the green LED comes on indicating a logic low state. If the input is above 2.7V the red LED is on indicating a logic high state. The inoperative window voltage levels can be adjusted, if required, by altering the reference levels at the inputs to the inverting and noninverting amplifiers, pins 7 and 2 respectively.

The supply voltage, V_{CC}, for the probe can be provided by clipping it to the supply rails of the circuit under test.

The potentiometer circuit shown to the left of the logic probe circuit was used to test the probe for proper operation. Applying the probe input P to the points A and B causes the red LED to come on, and touching P at points C and D results in the green LED to be lit.

J R Nowicki
Marlborough, Wilts.

Active Noise Cancellation

Car designers are now turning their thoughts to giving us a quieter ride. Helen Oughton reports on the latest active noise cancellation techniques.

If you drive regularly, you are likely to have been annoyed sometimes by the noise your car makes at certain speeds. Listening to your favourite music or radio program is fine at low speeds but on the open road at higher speeds, the problem starts. Low frequency noise, or boom, drowns the output from your speakers. Do you slow down and take longer on your journey, or continue with no entertainment but the boom of your engine?

Almost all vehicles are susceptible to low frequency boom in the passenger compartment, no matter what sound deadening material the manufacturer uses.

Control of low frequency noise and vibration by conventional methods can be very difficult. This feature looks at the causes of low frequency boom, and then explains an alternative technique which Lotus Engineering has developed to combat the problems of vehicle noise.

The Problem Of Noise

Noise in general is now recognised as a major pollutant in our lives. New legislation came into effect this year enforcing improved standards of noise in industry and in transport. The 'Noise at Work Regulations' are part of an EEC directive, and come under the Health and Safety at Work act in this country, defining noise levels for an eight hour working day.

Vehicle noise is no exception. People are spending more and more time daily in their vehicles, in the course of their work, or travelling to and from work. The car becomes a sanctuary in which the driver can listen to music or radio programs.

But most vehicles today are susceptible to low frequency noise or boom in the passenger compartment, which becomes severe at certain critical speeds. Noise control and comfort are becoming more important to the car owner. With increasing controls on speed in many countries, in-car comfort will gain in relative importance, while the car's top speed becomes less important.

Hitherto, noise control has been a low priority, a sort of 'bolt-on' refinement for the car manufacturer. However, manufacturers are now under increasing pressure to include effective and integral noise control as part of the overall design of a vehicle.

New environmental concerns exacerbate the problem. Car manufacturers are under pressure to reduce the wastage of resources and cut down harmful emissions into the atmosphere. Their response to this problem will be a drive to produce light-weight vehicles with smaller, more fuel-efficient engines containing three or four cylinders. Such engines are inherently noisier, with greater vibration levels. Lighter vehicles also possess lower natural attenuation of sound, and it will be significantly harder for the noise control engineer to maintain noise levels at current standards.

Lotus Engineering has conducted research on low frequency noise in a range of cars, from a sportscar to an average family saloon. The research took place in semi-anechoic chambers, described in more detail later. Briefly, a semi-anechoic chamber is a room with echo-free walls and ceilings and a normal floor to simulate reflections from a road surface.

The research showed that boom occurs in the passenger area at twice the engine frequency, typically between 70Hz and 200Hz. The frequency at which boom is worst depends not only on the type of car, but on the position of the person within the car. It is typically worst at about 4000rpm. The main sources of the noise are the engine and powertrain. Tyre contact with the road also makes a significant contribution.

Conventional sound deadening techniques work only at particular frequencies, and not across the full range produced by the engine. Suppressing boom below 200Hz by conventional methods is costly and adds significantly to vehicle weight, contrary to current weight and cost saving programmes. The problem is made more complicated because boom is generated from a number of sources such as engine mounts, drive-train, induction and exhaust manifolds as well as mechanical components (see Fig. 1).

Reduction in the stiffness of rubber engine mountings might help reduce noise, but would result in an unacceptable lack of control of engine movement, particularly in poor conditions.

Another solution which has proved impractical is the use of twin contra-rotating balanced shafts which rotate at twice the engine speed. These are dependant on certain engine speeds, and only deal with structural inputs through the engine mounts.

Adaptive Noise Cancellation

Adaptive Noise Cancellation is an alternative solution which gets round these problems. It uses electronic feedback to generate sound of the same frequency as the boom, but in antiphase with it. The boom is cancelled before the human ear can detect it happening. Adaptive Noise Cancellation can achieve noise reductions of around 20dB in a typical family car.

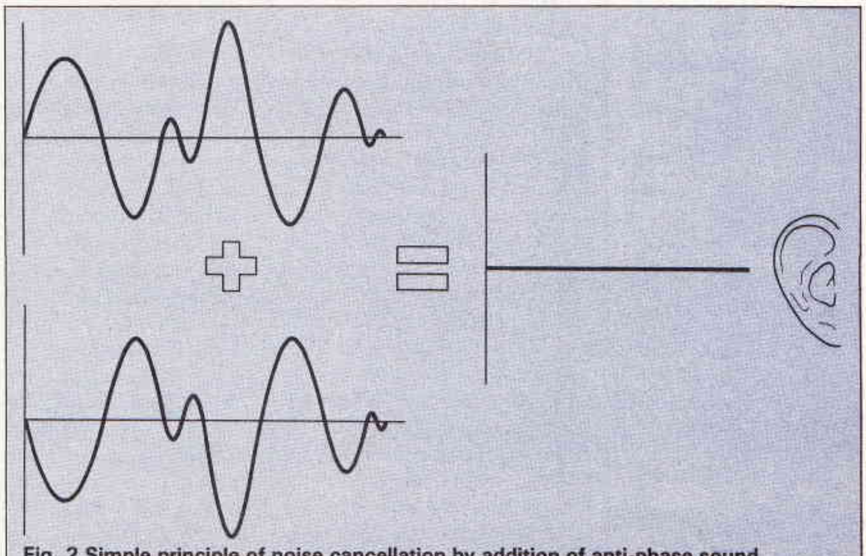


Fig. 2 Simple principle of noise cancellation by addition of anti-phase sound

Fig. 2 provides a simplified illustration of how Adaptive Noise Cancellation works. Sound is a series of pressure waves which the ear can detect and the brain can interpret. If two sources of sound are in antiphase, the high-pressure peaks from one source coincide with the low-pressure troughs from the other, and vice versa. The peaks cancel out the troughs, and no sound is detected by the ear.

Lotus Engineering has been involved with developing Adaptive Noise Cancellation techniques in association with Southampton University's Institute of Sound and Vibration Research (ISVR) since 1986.

These techniques have achieved significant improvements in vehicle noise, with noise reductions of up to 25dB being acheived within 0.1s of the frequency being reached. As this is too quick for the ear to detect, the passengers would only notice an apparently quieter car.

Currently the system is limited to frequencies up to a maximum of 400 Hz. Higher frequency cancellation is less easy to achieve due to the acoustic behaviour of the passenger compartment. However, higher frequencies can be suppressed using lightweight absorbtion materials.

A Noise Cancellation System

The Adaptive Noise Cancellation system developed by Lotus Engineering and ISVR includes microphones, an amplifier and loudspeakers, and a processor to control and generate the antiphase noise. Wide response microphones and loudspeakers are essential as low frequencies are involved.

A typical system uses eight electret microphones, carefully positioned within the roof lining of the passenger compartment to provide feedback to the processor (Fig. 3). Four loudspeakers and an amplifier with 10 to 20 watts RMS per channel capacity can be integrated with the in-car entertainment system.

A digital signal processing (DSP) microprocessor provides the intelligence required to cancel noise throughout the vehicle. The microprocessor is linked to the car's ignition system to sense engine speed. It combines this information with the input from the microphones to calculate and generate a suitable output at each loudspeaker. The output is in antiphase with the noise from the engine and car body, to minimise the sound pressure throughout the passenger compartment.

The DSP microprocessor used in the Lotus and ISVR system is a Texas Instruments TMS 320 series processor. It is anticipated that the complete computer will be reduced to one chip within three years, costing about $12-15.

As well as reducing noise produced by the engine, Adaptive Noise Cancellation can be used very effectively to cancel road noise below 250Hz. Suspension sensors detect the vibration before it is a noise. The DSP computer anticipates the noise and provides the correct cancelling waves. Again, the antiphase noise can be output through the in-car entertainment system's speakers.

Lotus have recently announced collaborative ventures with two West German companies.

Blaupunkt, who manufacture in-car entertainment systems, are now licenced to manufacture Lotus anti-noise systems. This will speed the integration of noise control with the in-car entertainment system, and will enable the rapid introduction of active noise systems into mass production.

The other company with which Lotus are collaborating is Carl Freudenberg. The aim is to develop an active engine mount and control system. An electrical transducer will be integrated into the mount to cancel the vibrations being passed through it. This gives a reduction in vibration while maintaining the stiffer mounts required for optimum control of engine movement.

Will Adaptive Noise Cancellation eventually become a standard feature on the average family car? Taking into account current requirements for smaller, more economical cars, and the trends towards more peaceful, comfortable lives for the 90s, the signs are that vehicle manufacturers will be under pressure to take noise reduction very seriously.

EXCESSIVE NOISE

Noise can often by annoying, especially if it keeps us awake at night or disturbs our concentration. However, at high enough levels for long periods, it can actually damage our hearing. It has long been recognised that in heavy industries such as steel making and shipbuilding workers were going deaf. Our ears are not designed to receive continuous loud noise from machinery, aircraft, rock concerts and personal hi-fi systems.

Inside the ear, sound passes down the ear canal to the ear drum, which converts the variation in pressure into vibrations. These pass through the middle ear to the cochlea, which contains about 30,000 very fine hair cells surrounded by fluid (Fig. 4). The hair cells convert the vibration into electrical signals in the nerves, which are interpreted by the brain as sound. When the ear is subjected to excessive noise the hair cells are destroyed, and never recover. Successive doses of noise gradually destroy more and more cells until a permanent hearing loss is noticed.

The first cells to be lost are those that work at about 4kHz. When the ear is severely impaired, all frequencies are affected, leading to a loss in comprehension of speech or music.

Hearing loss is a slow process. When we come out of a very noisy room, we may notice a slight ringing in our ears, but it soon goes away, and we do not realise the damage that has been caused until it is too late. Because we build up an understanding of different types of noise and speech, we may not notice the early signs of hearing loss.

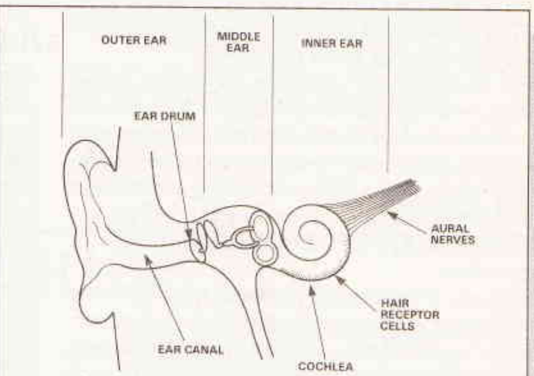


Fig. 4 Construction of the Ear

Research has recommended a maximum level of 90db(A) Equivalent Noise Level (Leq) for an eight hour day, though there is still some risk of impairment and 85db(A) has been adopted by the EEC as the level at which action should first be taken. 85db(A) is still loud — if you were standing only 2m away from someone, you would have to shout to make them hear.

These levels have been adopted by the new Noise At Work regulations, which now come under the Health and Safety at Work Act in Britain. Above 90db(A) Leq, all reasonable efforts must be made to reduce the noise, and hearing protection must be issued.

Fig. 3

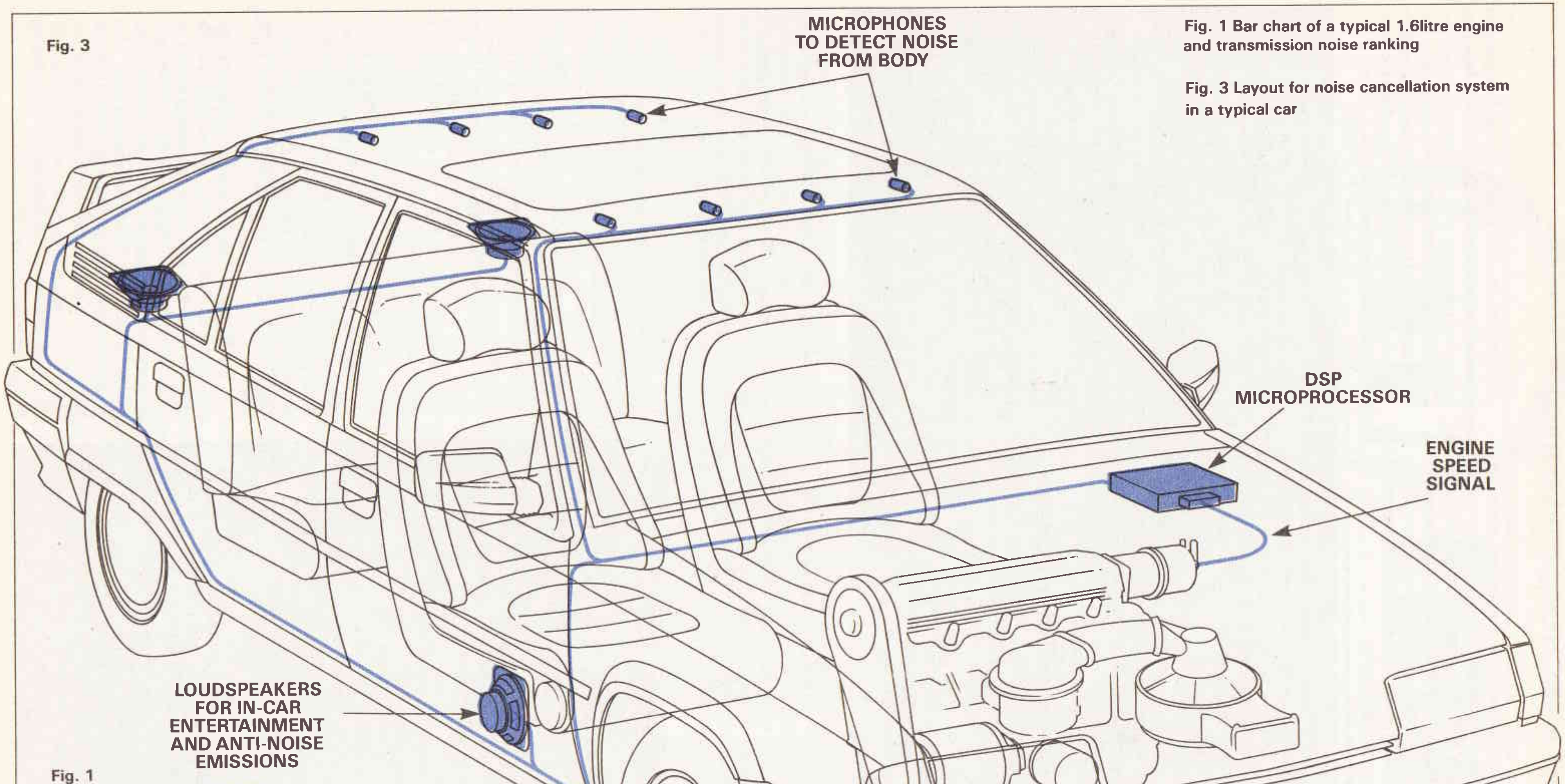


Fig. 1

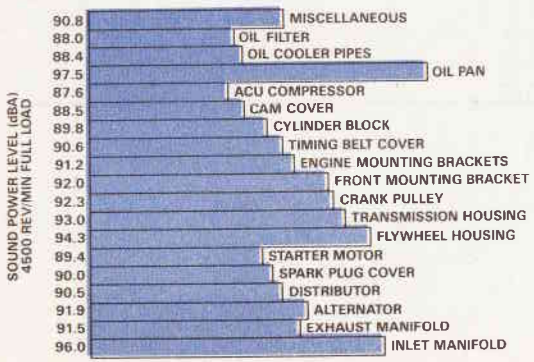


Fig. 1 Bar chart of a typical 1.6litre engine and transmission noise ranking

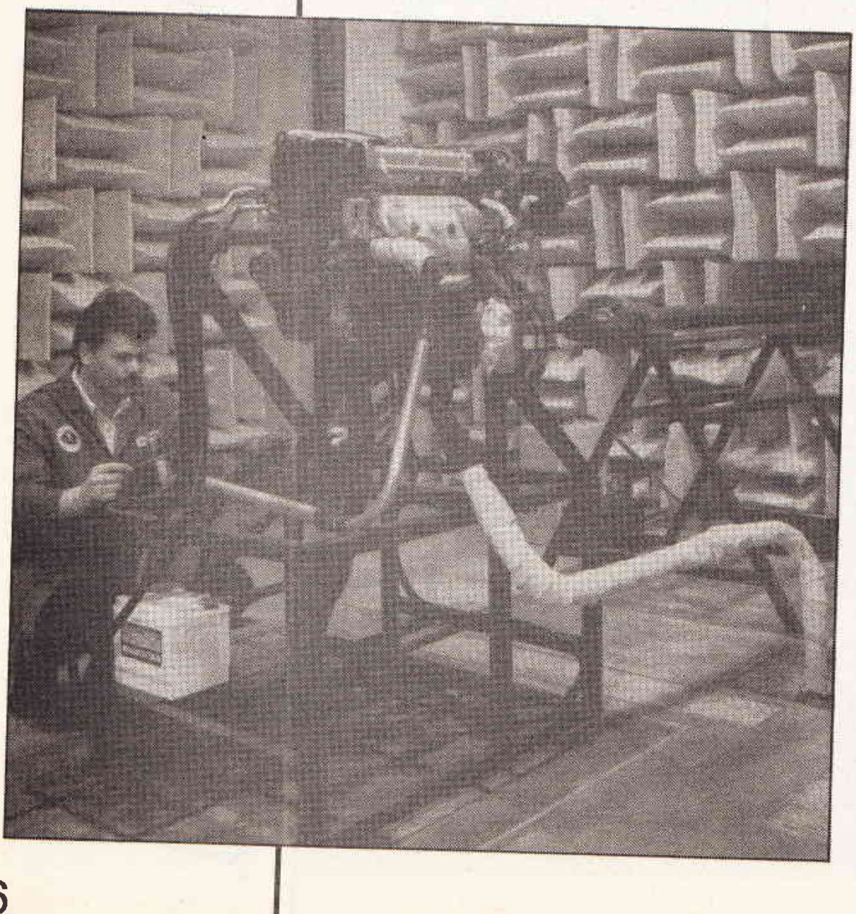
Fig. 3 Layout for noise cancellation system in a typical car

SEMI-ANECHOIC CHAMBERS

A vital tool to the noise control engineer is the semi-anechoic chamber. The chamber combines simulation of road noise conditions and isolation of noise sources, with the advantages of a stationary vehicle on a rolling road in controlled conditions. It makes testing faster and more accurate than could be acheived on a test track.

Semi-anechoic chambers are used to simulate the sound behaviour of a vehicle on a road. Anechoic means 'no refections', and anechoic chambers are designed to minimise reflections from any surface. On the other hand, the *semi*-anechoic chambers used for vehicle noise research allow reflections from the floor, but not from any other surface.

Noise measurements made in rooms with hard walls will include the sound reflected from the walls, as well as that radiated directly from the source. In a real situation, noise from a vehicle will be reflected only from the hard road surface. Noise radiated in other directions will be dissipated without reflection.



Reflected noise is removed by absorption at the walls and ceiling by the used of long, glass-fibre wedges. The depth of the wedges determines the lowest frequency level for which the absorbtion effect is valid — this is known as the cut-off frequency. Below this frequency, some reflection will occur, but at a dimished level.

There are many advantages in using a semi-anechoic chamber. Testing vehicles on a test track is limited by weather conditions, and it is impossible to control the test environment in terms of temperature, air flow and road surface. The noise emitted by a vehicle will be affected strongly by these variables.

The chamber also allows problems to be investigated while the vehicle is stationary on a rolling road, allowing the engineer access beneath and around a vehicle while it is effectively driving along. Vehicle noise may be transmitted through its structure, or transmitted through the air. The environment of a semi-anechoic chamber allows the engineer to isolate sound transmission paths, for example, by removing the steering wheel — hardly practical on the test track!

Smaller semi-anechoic chambers form an integral part of engine test bed procedure, pin-pointing those parts of the engine which-produce most noise, and which will produce most benefit if redesigned or modified. Fig. 1 shows the results of some of these tests.

Lotus Engineering has used two types of semi-anechoic chamber in their research. The vehicle chamber contains a rolling road capable of speeds up to 250 kph (155mph). Its size is 9.8m × 6.8m, and it has a cutoff frequency of 70 Hz (below which some reflection will occur). This is acheived by using 1.1m glass fibre wedges. The smaller engine cell is 6.8m × 5.8m × 3.8m, and has a cut-off frequency of 150Hz. Data from the cells is analysed using specially designed software, DATS, written by Prostig Computer Consultants Ltd.

ETI Audio news

Following closely behind the launch of the SY77 synthesiser workstation comes the TG55 from Yamaha, a rack mounted MIDI controlled tone generator that contains many of the features to be had in the SY77 featured in the audio news section last month.

The rack contains 74 preset samples in ROM. Quality is as good as CD reproduction as samples are again 16 bit quantised. Additional sampled sounds can be accessed via external wavecards.

Sampled waves can be mixed and blended by a digital filter system and voices can be edited in the usual variety of ways including volume, detuning and panning.

Apart from all the usual expressive effects obtained through the keyboard, Yamaha introduce velocity switching. This effect brings different elements to the musical foreground depending on how hard the keyboard is played. The TG55 contains 34 effects programs giving a multiplicity of reverb effects through to distortion. A complete drum set accompaniment is also available with another 64 voices.

The TG55 rack-mount tone generator retails at £749.00.

A personal stereo about the same size as a cassette case, to be carried in your pocket, has been launched by Panasonic in April.

The new S series cassette players offer full remote control, lcd display, the now familiar extented bass system, Dolby noise reduction and a clock. The remote control facility allows you to play, stop, and all the rest of the mechanical functions from one button. This makes it easier to operate while still in your pocket. The clock enables two time-settings to be programmed with an alarm function. Auto-reverse playback will save you having to turn the cassette over.

Maplin are offering a range of bass guitar amplifiers at a variety of power outputs from 15-75 watts for practice purposes or local performance.

The 15 watt version comes in a tough wooden cabinet with loudspeaker and a 3 channel equaliser. At the top end, the 75 watt amp contains reverb, three channel equaliser and a 'bright' switch to give greater signal presence. Pre-amp out and power amp in are available via jack sockets on the back.

The 15 watt version costs £54.95 and 75 watts of guitar power will cost you £169.95.

If you have the musical ideas and the MIDI software to record them, you're only one step away from a professionally recorded song, thanks to the Engine Factory's new Micro Productions service.

They will tidy up the raw data, select the right sounds for the job, arrange, produce and mix a CD quality production onto cassette, DAT or HiFi Video, all for a lot less than the equivalent work would cost in a conventional studio.

Great care has been taken in providing clients with an extensive, up to the minute range of sounds, from such industry standard machines as the Akai S1000 (16 Bit Stereo Sampler) and the Korg M1 (Al Synthesis Workstation). In fact over 200 sound sources are available at the click of a mouse, within a single track.

Further information and a demo cassette call The Engine Factory on 081-650-1033.

Compact Disc players are getting cheaper. Sony's new discman, a budget portable CD player enters the competitive field.

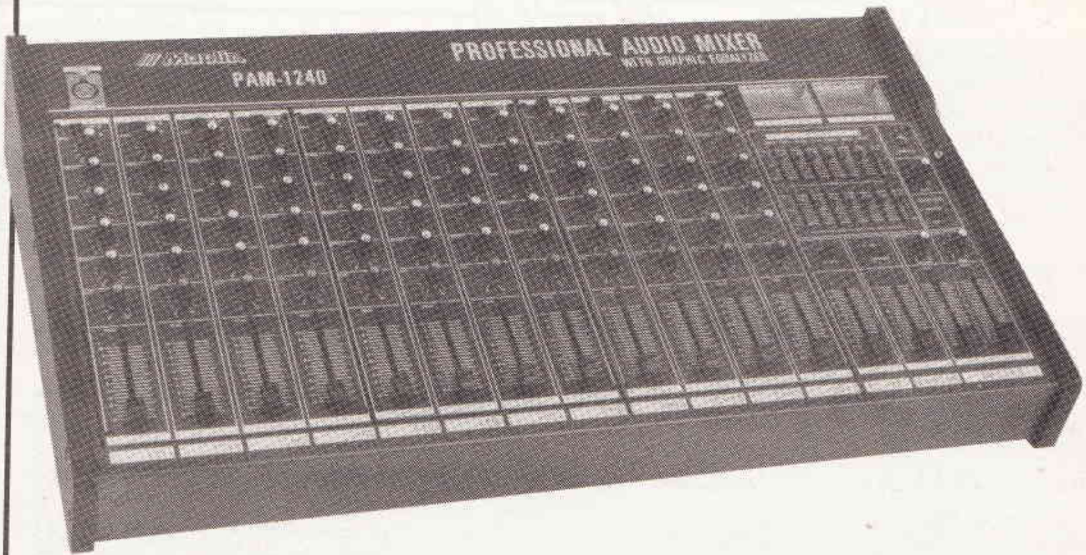
Weighing only 450g, and with a frequency response of 20-20kHz, this new player consumes only 1.2 watts of power.

In line with more bass appeal now demanded by the headphone brigade, the portable has a three position bass switch to give a varied degree of boost to the headphones. If normal playback is required through the home hi-fi, a 1 volt line out jack is supplied.

The D22 contains all the normal music-search functions along with the option of infra-red remote control.

The Sony D22 carries a price tag of £149.99.

MAPLIN AUDIO MIXERS



Paul Freeman introduces the new range of budget mixers from Maplin, and takes a detailed look at the 12 channel version.

REVIEW

A range of budget mixers has been launched by Maplin this year featuring 6, 8 and 12 channel inputs into two channel stereo out. Over the last ten years, the explosive growth in the availability of music-making equipment at prices that many people can afford has been such that the demand for a decent mixing desk has become apparent. Maplin may be filling this gap with its range of budget mixers. Here we'll have a look at the 12 channel version.

Although mixing desks come in a variety of shapes and sizes they all have the same basic facilities. What can vary is the quality of sound output and the number of channels coming in and going out.

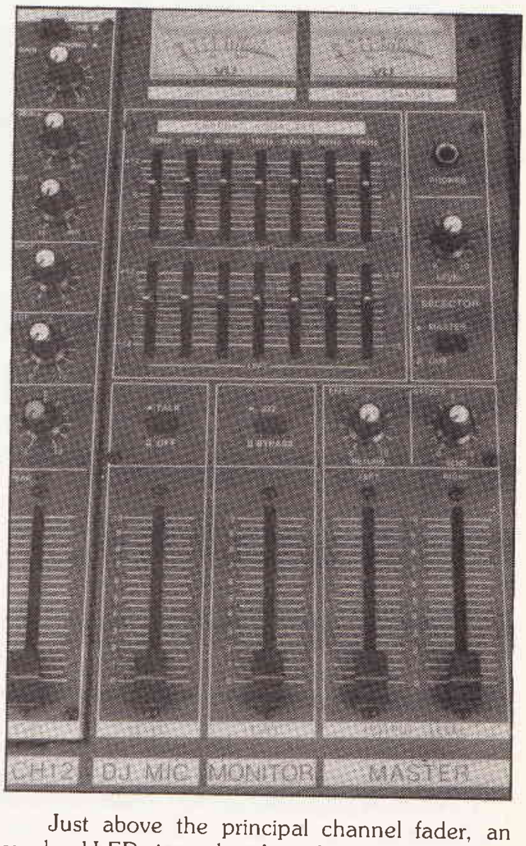
This mixing desk, the largest of the Maplin range of three, is just under 750mm long and over 400mm deep. All twelve channels are identical in their front panel appearance, but the first ten have microphone or line inputs, and the last two, with higher impedance, have phono inputs only. Now what about the control line up?

We'll start at the top and work down each input channel. The first control is a line/microphone selector to switch the input from microphone to anything less sensitive at line level. Below this selector comes a gain control to preset the input level. This can be useful if your input signals vary wildly in level. Adjustment here will then balance the main fade controls.

The statutary treble and bass controls give ±12dB at 100Hz base end and ±12dB cut and boost at the top end (10kHz).

Next comes the all-essential pan control, which divides your mono signal into left, right and centre of the stereo field output. The effect send is below the pan pot, sending a proportion of the input signal to an effects box. The effects box can modify the sound in some way. It could be reverb, echo, chorus, phasing or flanging.

The cue control, or pre fade listen (PFL) as it is more professionally known, comes next down the chain of knobs to twiddle. This adjusts the volume of the incoming signal to the headphones only. It goes without saying that it will not affect what goes out from the stereo output jack. There is a switch to change the headphones from console-out to PFL at the master output end of the desk.



Just above the principal channel fader, an overload LED gives a handy and quick indication of overdrive to the input amplifier. The LED cuts in at around +4dB.

This completes the line up for each channel.

There are a few general points to bear in mind about the first ten channels. All op-amps are of a TL072 type and these were presumably chosen as they have an equivalent input noise of $18nV/\sqrt{Hz}$. Each input channel has a cascade of five op-amps from the mic or line before reaching the mixing bus. The signal then has to go through another two op-amps per stereo channel before it arrives at a record output. The more the signal has to go through the greater the overall noise contribution, so it is in the interests of the designers to keep the number of cascaded op-amps as low as possible.

All microphone inputs are unbalanced via a choice of input connectors, XLR or ¼inch jack, on the back of the desk. A DJ mic input is available via an XLR connector on the top of the console. This mic signal goes through only 4 op-amps from input to record out.

At the right hand end of the mixing desk as on all desks are the output controls, controlling anything downwind of the mixing bus. Firstly there is a DJ mic fader with a talk-through muting switch just above. This cuts line levels by 12dB for the purposes of talk through.

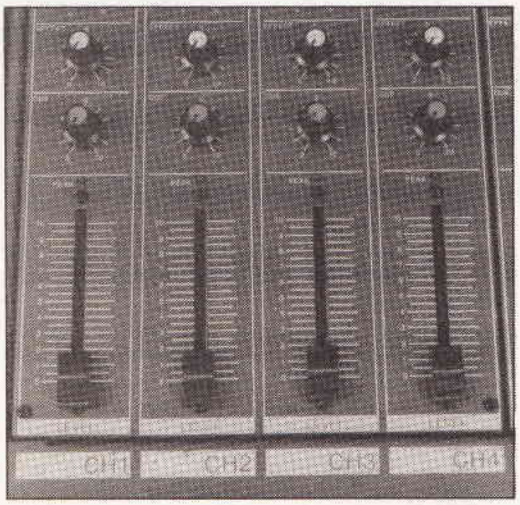
Next comes a studio speaker monitor level and above this an equaliser bypass switch. While we are on the subject of graphic equalisers, the desk comes with a seven-channel graphic equaliser for each output giving ±12dB of cut or gain at each centre frequency. Equalisers can be effective if stray resonances occur during each recording in the studio but the advantages come at the price of introducing more noise into the chain. Centre frequencies are given in the specifications at the end of this review.

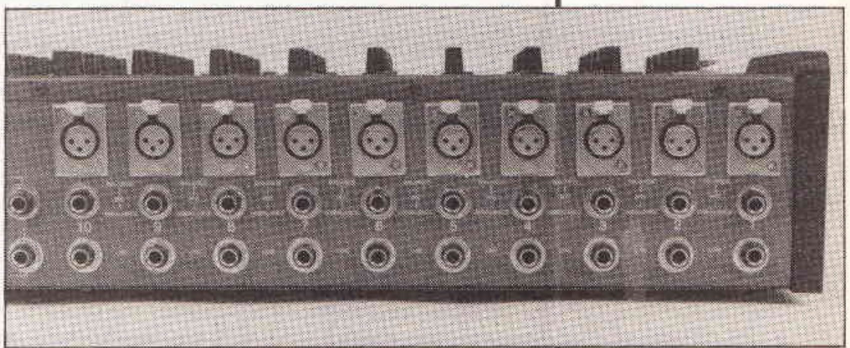
On the far right-hand side is a headphone jack and level control, a master/cue switch and effect send and return controls. Finally the two output level master faders with VU meters complete the line up.

One must accept that this is budget mixer and as a result there are limitations. The first and foremost is one of noise contribution. The quoted signal-to-noise ratio of 70dB for mic inputs and 80dB for line inputs is about right compared to the measured value but better figures could be achieved with careful design and choice of components. One also has to be careful of how many 'live' inputs there are feeding into the output bus high fader levels otherwise the noise may become unacceptable. I've always had reservations about introducing graphic equalisers into the signal path, but I was pleased to hear that the noise contribution made by the graphic was at an acceptably low level and in my mind could give a worthwhile contribution if required. A 50dB crosstalk figure between channels would be a worrying feature if complete single channel drive was needed, but this is an unlikely event in a live and complete stereo sound field. Personally I would prefer the headphone output jack to be on the front vertical panel of the desk instead of on top with the wire trailing across the desk to get in the way, but having said that the Maplin range of audio mixers represents good value for money and they could find a place in the home studio in what has now become a boom industry.

The retail prices are:

6 channel	£279.95.
8 channel	£399.95.
12 channel	£499.95.





SPECIFICATIONS

INPUT SENSITIVITY

Mic	3mV into 10K
Phono	3mV into 47K
Line	150mV into 100K
Return	775mV into 100K

OUTPUT LEVEL

Master	1.5V/600R
Max	8V/600R
Monitor	1.5V/600R
Record	0.775V/600R
Send	1.5V/600R

S/N RATIO

Mic	70dB
Phono	70dB
Line	80dB

DISTORTION
Less than 0.1% (At rated output)

FREQUENCY RESPONSE
20Hz-20 kHz <0.5dB

EQUALISER
Centre frequency 60Hz, 150Hz, 400Hz 1kHz, 2.4kHz, 6kHz, 15kH
Boost/cut range ±12dB at centre frequency

TONE CONTROL
Bass ±12dB at 100Hz
Treble ±12dB at 10kHz

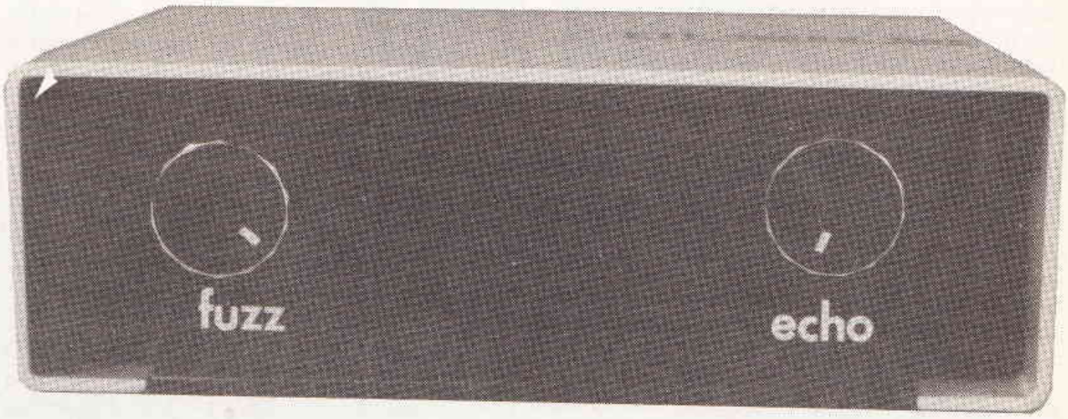
HEADPHONES
Impedance 4 – 50R can be used

RELAY DELAY TIME
Approx 2 seconds

PEAK INDICATOR
5V-6V at master level setting maximum

CROSSTALK
Master 50dB
Monitor 50dB
Record 50dB
Send 50dB

THE FECKO BOX



Got a guitar? Keith Brindley explains how to create your own fuzz and echo effects using the ETI Fecko Box.

The Fecko Box is essentially a new variation on old guitar effects boxes. Firstly it gives a fuzz effect — distorting the sound of your guitar with a soft distortion. Secondly, and more unusual, it creates an echo effect which, combined with fuzz or by itself, gives the illusion of reverberation similar to that obtained inside a large auditorium.

Fuzz, as the story goes, was 'invented' by the Kinks. Apparently, in the days before fame and fortune allowed the effect to be generated electronically, one of the group's loudspeaker cones split. As they couldn't afford to replace it — they used it! And so fuzz was born.

Since then, of course, fuzz has been created successfully in several ways. Most of these (see *How It Works*) rely on amplifying the incoming guitar signal till the amplifier distorts as it limits. ETI's Fecko Box creates fuzz in a slightly unusual manner, giving a more mellow sound than most fuzz boxes.

Echo has been created with a number of methods and used in various ways. Strictly speaking, echo is simply repetition of a signal. As such it has limited use. If the delay between the signal and its repetition is sufficiently long it may be used musically, say, to play back a complete bar of music immediately after the original bar. However, a bar of music could be three or four seconds in length and creating such a delay is not easy.

A more common effect, using short delay echo, is *reverberation*; created by feeding back part of the delayed echo so that it is re-delayed. The overall result sounds like the instrument is being played in a large auditorium, with multiple reflections from the internal walls and surfaces prolonging the time until the sound dies away. A similar effect is obtained when you sing in the bath — multiple echoes from the bare walls of the bathroom combine to create reverberations! Reverberation time is the time it takes for the resultant sound to fall by 60 dB after the original sound has ceased.

Before electronic delay circuits became feasible, echo (and hence reverberation) was only possible using mechanical systems. Early methods used a spring, suspended between two transducers and connected to amplifiers. Spring-line units are still available and work quite well, although being mechanical they are naturally susceptible to vibration

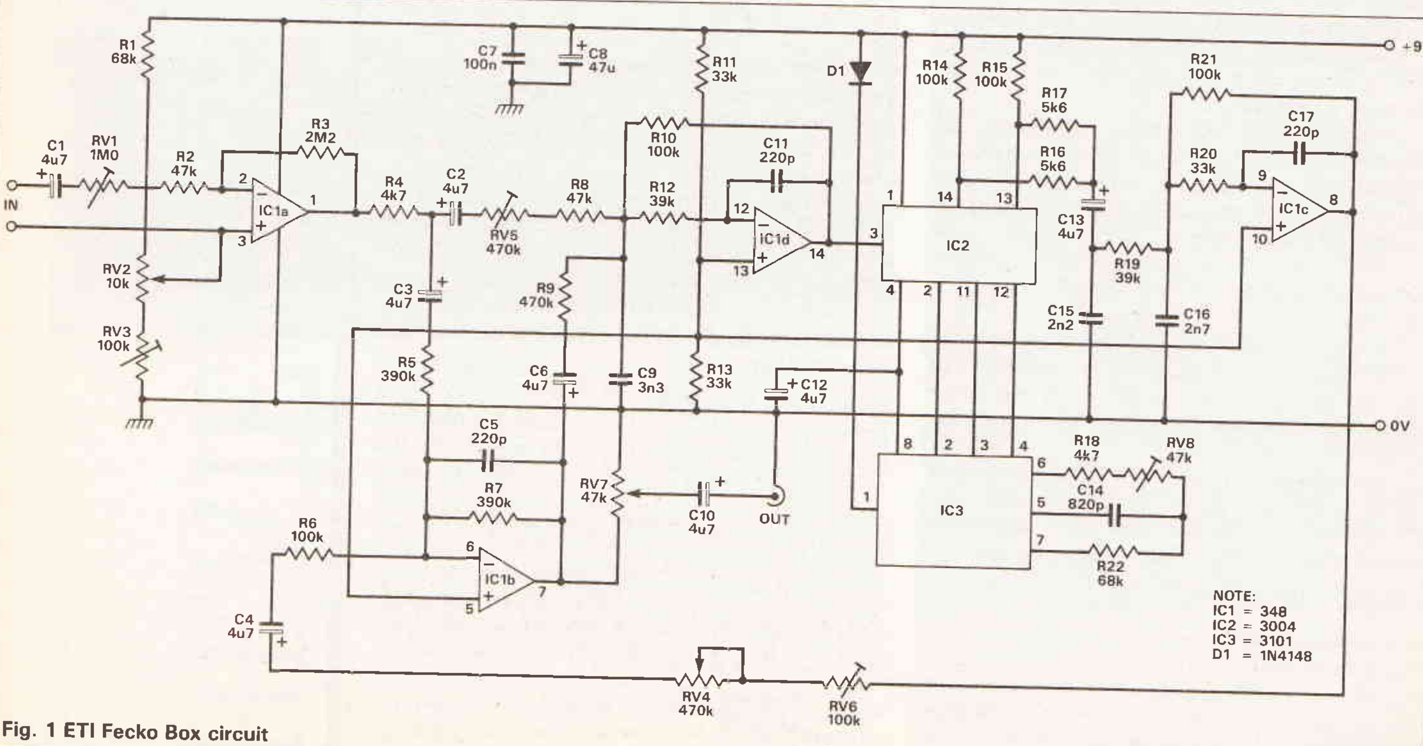


Fig. 1 ETI Fecko Box circuit

and interference.

A more reliable method uses a magnetic tape system, similar to a conventional cassette or reel-to-reel tape recorder. Usually it comprises a tape loop coupled with a recording head and one or more separate playback heads. Any signal recorded is replayed later from the playback heads. The finite speed of tape as it moves from the record head to the playback heads defines the time delay between the original sound and the echo. The main drawback of the tape loop method is simply the bulky mechanics, although long delays are possible.

Electronic methods of creating echo may be analogue or digital in nature. Digital echo is created by converting the original analogue signal into a digital signal, writing it into a digital store, then reading it from the store and finally reconverting to analogue for replay.

Over the last few years, however, it has been normal to create echo and hence reverberation using the *analogue delay line* principle, in which the original signal is sampled and each sample is passed along a line of storage capacitors. At the end of the line the samples are recombined to give a delayed echo. The number of storage capacitors and the speed with which the samples are passed along the line defines the delay. Analogue delay lines of this type are often called *bucket-brigade delay* lines. The ETI Fecko Box uses this method.

Delay obtained in this sort of echo generation system is limited to around 20 or 30 ms. This is virtually inaudible as a single repeat, however, and so by feeding back the echo to the input again, echoes of the original sounds are re-delayed such that a reverberation effect is obtained.

The output signal amplitude of the Fecko Box can be preset between zero and about 3V, so the Fecko Box may simply be connected in-line between your guitar and your usual guitar amplifier. With a larger output amplitude, a direct input (DI) to a mixing desk (or even your hi-fi amplifier's line input) can be made.

Construction

The component overlay for the project is shown in Figure 2. The printed circuit board requires just one link. After inserting and soldering the link, solder in all passive components. Leave the two potentiometers until last, because otherwise they may make the board a bit tricky to handle.

Although it's by no means essential to use integrated circuit sockets, it's probably advisable as integrated circuits IC1 and IC2 are sensitive to static, and unless adequate precautions are taken, they may be damaged when soldered. PCB pins are a good idea, as they make off-board connection considerably more straightforward when the board is inserted in the case.

Insert and solder in diode D1, then insert all integrated circuits into their sockets (or solder directly to the board, if you prefer). Finally, insert and solder the two potentiometers. This completes construction of the PCB.

Although you do not need to use any particular case, it's probably a good idea to use a metal case, earthing it to 0V to help prevent interference from external sources. Make sure the input ground connection is isolated from 0V.

Power (that is, 0V) should be switched onto the board when a plug is inserted into one of the jack sockets — a fairly standard practice on guitar effects boxes. However, to ensure input isolation, switching should occur via the *output* jack socket. Make sure you use screened leads to connect the input and output between jack sockets and printed circuit board.

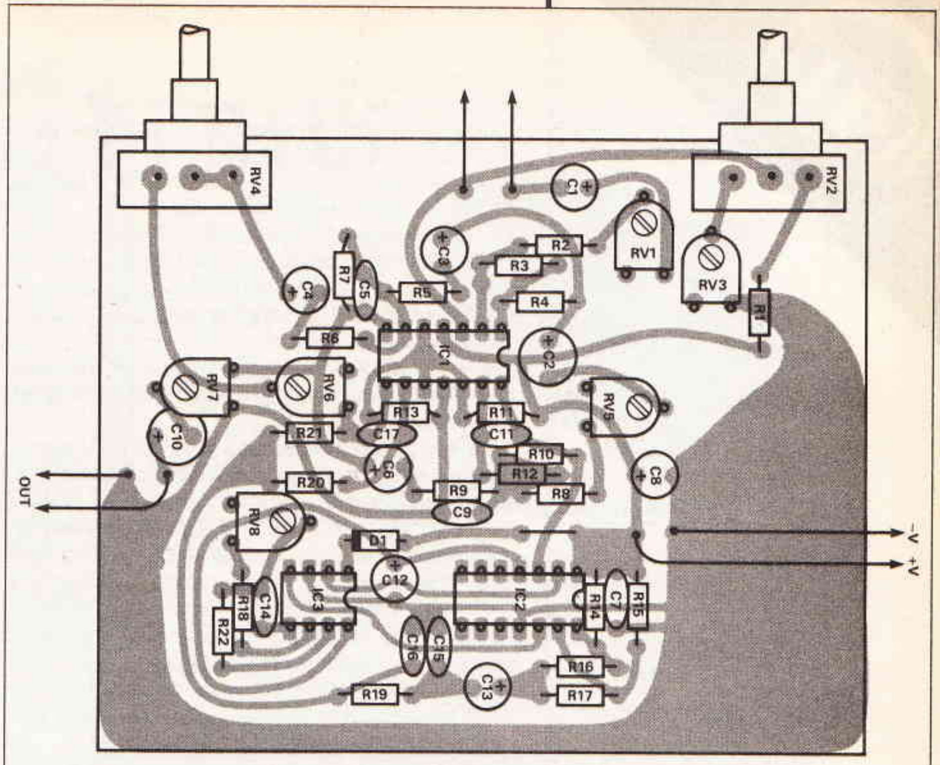


Fig. 2 Component overlay for the Fecko Box

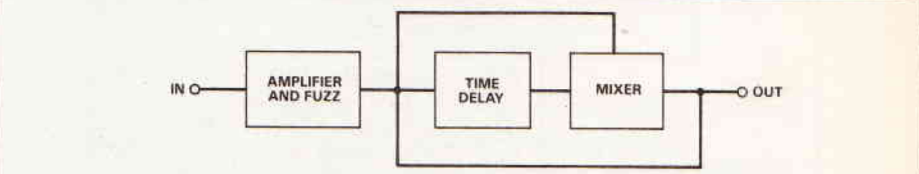


Fig. 3 Block diagram of the Fecko Box

Setting Up

Initially, set all presets to mid-position with the exception of RV6 which should be set fully clockwise (viewed from the component side of the board). Set the two potentiometers fully anti-clockwise. With these settings, the project should give an output for any suitable signal input.

To set up the project for minimum distortion and maximum signal-to-noise ratio, you ideally need a signal source of around 1kHz at 100mV and an oscilloscope. However, you can obtain a suitable approximation from a signal direct from your guitar, an amplifier to amplify the outgoing signal (your hi-fi system will do nicely) and a pair of ears. An oscilloscope is by no means essential. The idea is to adjust the amplifying stages of the project for maximum gain without distorting the signal due to limiting. This may seem an odd requirement for what is effectively a distorting effect, but there will be times when you want an undistorted guitar sound.

Using the oscilloscope to monitor the output of op-amp IC1a, use preset RV1 to adjust the gain so that the output signal is a maximum without being clipped due to limiting. Without an oscilloscope, just listen to the output of the project — when it clips, you'll hear it.

Next, turn potentiometer RV2 slowly clockwise. At the same point you will observe on the oscilloscope clipping on one side of the signal. The further RV2 is turned clockwise, the greater the extent of clipping. With RV2 fully clockwise, adjust preset RV3 to give a maximum amount of clipping without total loss of signal output. Turn the potentiometer fully anti-clockwise (clipping should be totally eliminated). You will need to adjust presets RV1 and RV3 again, when your guitar is fully connected.

The following procedure need only be carried out once. Monitor the output of op-amp IC1c with the oscilloscope. Adjust preset RV5 for maximum gain without clipping. Next, turn potentiometer RV4 fully clockwise. Slowly turn preset RV6 anticlockwise. At some point the circuit will start to oscillate — turn preset RV6 back to stop oscillation. Turn potentiometer RV4 fully anticlockwise again.

Now you need a guitar signal. Repeat the steps of adjusting the gain of op-amp IC1a and clipping levels, using presets RV1 and RV3 and potentiometer RV2. Now preset RV7 to give the required output signal amplitude.

And that's it. Turning potentiometer RV2 clockwise gives fuzz. Turning potentiometer RV4 gives reverberation.

One final adjustment to project performance may be made by adjusting preset RV8, which controls the frequency of the oscillator stage built around integrated circuit IC3. With preset RV8 fully anticlockwise the oscillator frequency will manifest itself as an audible whistle in the output. Turning RV8 clockwise increases the frequency till it goes above hearing range. You can also adjust RV8 to give an optimum frequency response, suited to an individual guitar. It's worth nothing that, as you adjust RV8, you cause the project to generate the well-known and common phasing effect.

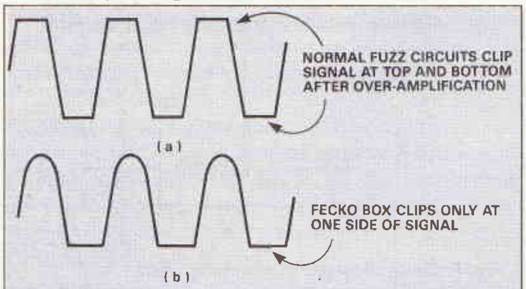


Fig. 4 Output signals of fuzz boxes (a) normal fuzz circuit (b) Fecko Box fuzz circuit

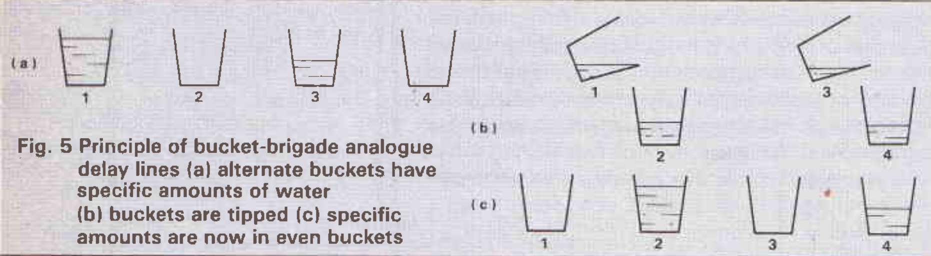


Fig. 5 Principle of bucket-brigade analogue delay lines (a) alternate buckets have specific amounts of water (b) buckets are tipped (c) specific amounts are now in even buckets

HOW IT WORKS

A block diagram of the whole project is shown in Figure 3. Three main parts are apparent. The first amplifier (built around op-amp IC1a) has a controlled bias arrangement, such that the output signal may be clipped by a varying amount to create a fuzz effect.

The usual way of creating fuzz is to overdrive an amplifier so that clipping occurs at both sides of the amplifier's output signal (Figure 4a). The Fecko Box operates in a slightly unusual manner by clipping only one side of the signal (Figure 4b). This is performed by varying the bias to the non-inverting input of the op-amp via potential divider chain R1, RV2 and RV3, offsetting the output DC level. The potentiometer RV2 provides front-panel control of fuzz, varying from zero to maximum, while preset RV3 is used to set the maximum amount. Preset RV1 sets overall gain for the amplifier. Note that input is referenced to the bias potential, not 0V, and so care should be taken to isolate input leads from any 0V potential, such as the case.

Time delay is created in the Fecko Box with a bucket-brigade delay line, the principle of which is shown in Figure 5 using buckets of water as an analogy. The first stage of the analogy (Figure 5a) sees alternate (odd) buckets filled with specific amounts of water. At the second stage (Figure 5b) the buckets are tipped, pouring water from them into the next (even) buckets in the line. In the final stage (Figure 5c) the odd buckets are empty and even buckets now hold the specific amounts. Next the even buckets are tipped into the next odd buckets, and so on. Effectively, water is passed along the line, bucket by bucket.

In a bucket-brigade delay line an analogue signal is stored as charges on a line of capacitors (the chip designers decided the problems of water leaking from buckets might create a bit of a mess!) But the principle is similar. Sampling and signal delay is performed by the integrated circuit IC2, while the clock function of IC3 times the transfer of charges from capacitor to capacitor along the line. The frequency of the clock signal is determined by components R18, R22, C14 and RV8. The preset RV8 allows adjustment.

When sampling of an analogue signal occurs, it is necessary to provide pre- and post-sampling filtering. This is carried out by circuits associated with op-amps IC1d (pre-sampling filter) and IC1c (post-sampling filter). Both are straightforward low-pass filters, with cut-off frequencies around 7kHz.

Op-amp IC1b and the associated components form an audio mixer, mixing signals from the first amplifier and the time delay. The potentiometer RV4 and the preset RV6 define the amount of delayed signal, such that the preset is used to set the amount just before oscillation (due to feedback) occurs.

Overall output level is determined with preset RV7. Any amount of signal amplitude between zero and around 3V can be obtained.

PARTS LIST

RESISTORS (all ¼W, 5%)	
R1	68k
R2,8	47k
R3	2M2
R4,18	4k7
R5,7	390k
R6,10,14,15,21	100k
R9	470k
R11,13,20	33k
R12,19	39k
R16,17	5k6
RV1	1M miniature horizontal preset
RV2	10k linear potentiometer
RV3,6	100k miniature horizontal preset
RV4	470k linear potentiometer
RV5	470k miniature horizontal preset
RV7,8	47k miniature horizontal preset
CAPACITORS	
C1,2,3,4,6,10,12,13	4µ7, 10V radial electrolytic
C5,11,17	220p ceramic
C7	100n polyester
C8	47µ, 16V radial electrolytic
C9	3n3 ceramic
C14	820p ceramic
C15	2n2 cermaic
C16	2n7 cermaic
SEMICONDUCTORS	
IC1	348
IC2	3004
IC3	3101
D1	IN4148

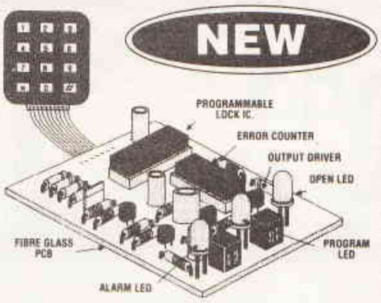
MISCELLANEOUS

PCB, battery and clip
Jack sockets (one of which should have an insert-to-make contact)
Case

BUYLINES

Most, if not all, parts are obtained from mail order companies. Integrated circuits IC2 and IC3 may be obtained from Electromail (part numbers 631-288 and 631-301).

PROGRAMMABLE ELECTRONIC LOCK KIT



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XK131 .... **£19.95**

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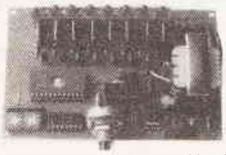

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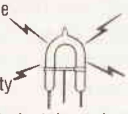

Produces an intense light pulse at a variable frequency of 1 to 15Hz. Includes high quality PCB, components, connectors, 5Ws strobe tube and assembly instructions. Supply: 240V ac. Size: 80x50x45.
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Includes all components (+ transformer) for a sensitive IR receiver with 16 logic outputs (0–15V) which with suitable interface circuitry (relays, triacs, etc details supplied) can switch up to 16 items of equipment on or off remotely. Outputs may be latched to the last received code or momentary (on during transmission) by specifying the decoder IC and a 15V stabilised supply is available to power external circuits. Supply: 240V AC or 15–24V DC at 10mA. Size: (exc. transformer) 9x4x2 cms. Companion transmitter is the MK18 which operated from a 9V PP3 battery and gives a range of up to 60ft. Two keyboards are available – MK9 (4–way) and MK10 (16–way).

MK12 IR Receiver (inc. transformer) **£19.55**
MK18 Transmitter **£8.95**
MK9 4–way Keyboard **£2.75**
MK10 16–way Keyboard **£7.95**
601133 Box for Transmitter .. **£2.95**

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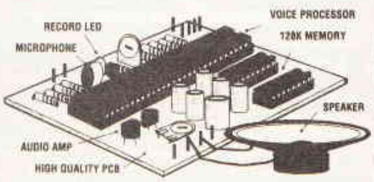

This simple to construct and even simpler to operate kit will record and playback short messages or tunes. It has many uses – seatbelt or lights reminder in the car, welcome messages to visitors at home or at work, warning messages in factories and public places, in fact anywhere where a spoken message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

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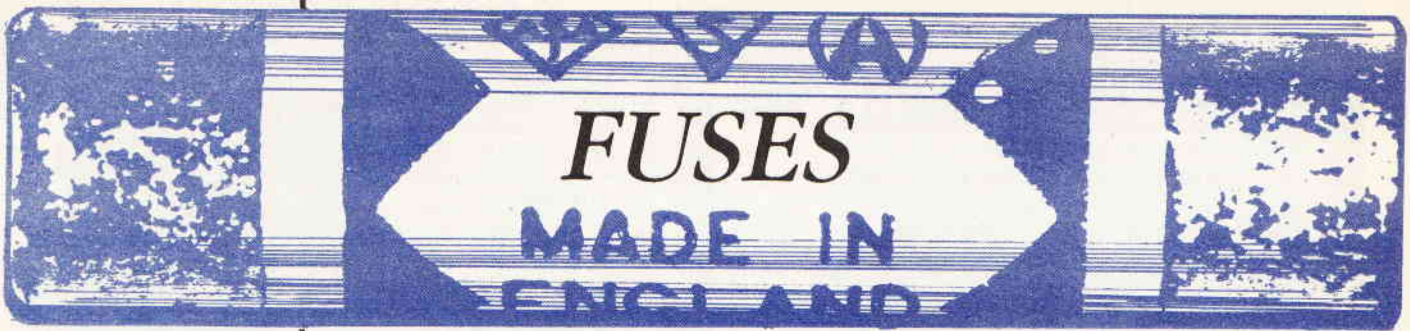

FUSES

Brian Kendal shows there is more to fuses than meets the eye

SAFETY

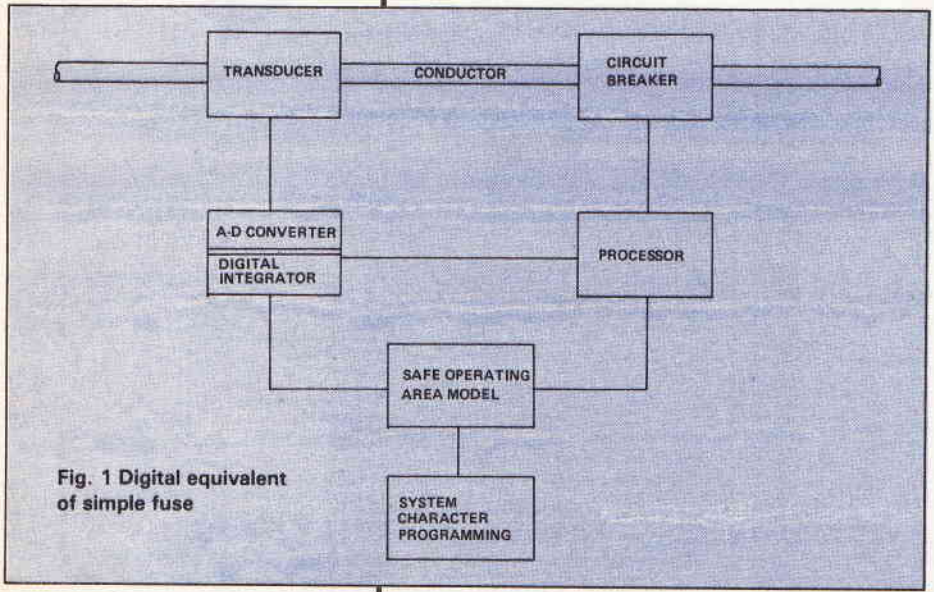

Fig. 1 Digital equivalent of simple fuse

The fuse is probably the least understood component in common use today. Furthermore, the popular belief that it is merely a piece of wire which melts when the current passing exceeds the quoted rating is not only inaccurate but, under certain circumstances, a danger to the equipment which it is supposed to be protecting.

Ideal Protection

Before looking further into the operation of fuses themselves, let us consider what protection circuitry would be necessary if they had never been invented.

Firstly, the current flowing in the circuit would have to be continuously monitored. The most effective way of achieving this would be by means of a current transducer, the output of which would be fed to a microprocessor via an analogue-to-digital converter.

The micro would need to determine whether excessive current flow was due to a natural variation, for example: the initial surge due to capacitors charging on switch-on, or due to a fault condition. This of course, would be incorporated in the software which numerically integrates the current, giving a measure of the thermal stresses in the protected circuit, match this against a map of the safe operating area of the particular circuit.

Assuming that this can satisfactorily be achieved, on detection of a fault condition, the output signal must then open the faulty circuit. This would most conveniently be achieved by a small power amplifier driving a circuit breaker capable of breaking the maximum fault current, which in mains circuits may well be in excess of several hundred amperes.

Such a protection circuit could doubtless be developed and, when placed on the market, sell for several hundred pounds. In practice, the designer would not even consider such a complex solution — instead he or she fits a miniature fuse.

Surprising as it may seem, the miniature fuse performs all the functions described previously and at a cost of only a few pence as long as the correct type and rating has been specified in the first place.

Fuse Characteristics

Most users select a fuse according to its rated current (I_n) believing that above this level the fuse will blow, thus safeguarding the circuit. This is a misconception, for the rated current is that which the device will carry continuously without degradation. Thus if the normal current in a circuit is 500 mA, then that is the rating of fuse which should be fitted. To cause the fuse to blow, the current will have to be much higher than this. The lowest current which will cause the fuse to melt is called the minimum fusing current (I_m) and its ratio to I_n is called the fusing factor. Typically the fusing factor is in the order of 1.5-2.0. Thus a 500 mA fuse will normally fail at a current between 750 mA and 1.0 A.

Considerable difficulties are experienced in determining I_m and the fusing factor, but these are circumvented by specifying current levels at which the fuse should not (or should) break within a given time. These levels are called the conventional non-fusing current and conventional fusing current respectively.

A typical specification for this is the BS 4265 requirement for miniature fuses which requires that the fuse under test should not fail when tested for one hour at 1.5 I_n.

A fuse's country of origin is important. For example, in the United States, standards require that miniature fuses should break within one hour at 1.35 I_n. In view of this, fuses from European and U.S. sources are not generally interchangeable.

A further consideration in the specification of a fuse for a particular purpose is the time necessary for operation when subjected to a high fault current. For example: a time delay or anti-surge type will take far longer to break than a fast acting fuse. Fast acting fuses to BS 4265 (Cat F) must break within 20 ms at 10 I_n whilst anti-surge types (Cat T) must take from 20 to 300 ms. Super-fast-acting and super-time-lag types are also available.

Fuse Rating (BS 4265)	*Max volt drop at I_n* F type	T type
50mA	7V	3.5V
500mA	1V	900mV
1A	200mV	150mV
5A	130mV	100mV

Table 1 Some typical fuse values

In the design of a fused circuit, consideration must also be given to the DC resistance of the fuse itself. As a fuse is a heat operated device, those intended for very low current ratings must necessarily have a relatively high resistance. The maximum permitted voltage drop is strictly controlled by standards of which some typical values are shown in Table 1.

From this it will be seen that the maximum voltage drop across a 50 mA type F fuse is 7V. However, as the conventional fusing current for these fuses is 2.1 I_n, a circuit voltage of 14.2V could be required to cause operation. As the supply voltage may well only be at this level, the fuse could hardly be blamed for failing to give adequate protection!

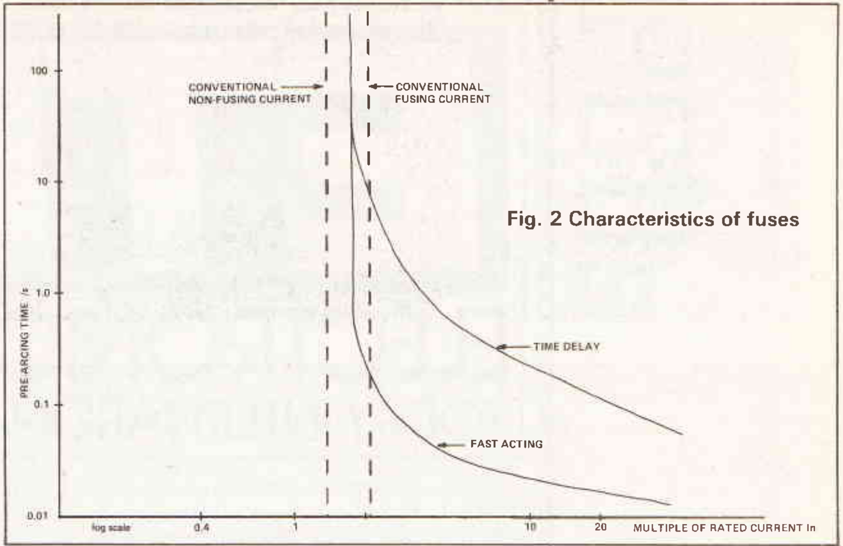

Fig. 2 Characteristics of fuses

After The Break

Another misconception is formed by the belief that once the wire melts, that is the end of the operation. Nothing could be further from the truth, for the failure of the wire is only the prelude to the most important part of the operation — the arcing period.

As the fuse element disintegrates, current flow does not cease immediately but continues through an electric arc. The duration of this arc (known as the arcing time) is very dependent on the parameters, and particularly the inductance, of the circuit to which it is attached. So important is this, that the period is often further broken down to itemise the period immediately prior to melting, referred to as the pre-arcing time.

When the arc is established, it effectively inserts a high resistance within the circuit, rapidly decreasing the current which eventually falls to zero. It is possible to design the fuse such that the arc voltage greatly exceeds that of the supply with the result that the fault current is rapidly eliminated with consequent reduction of the stresses imposed on the circuit. This is usually achieved by embedding the fuse element in a sand filler which constricts the arc diameter, considerably increasing its resistance and giving rise to the rapid current limiting action required.

Fuse Safety

The installation of a fuse is the cheapest and most effective circuit protection available today. To achieve this, a fuse with the correct characteristics and of the correct rating has to be chosen. It is hoped that this short article has given constructors an insight into the design and characteristics of fuses, enabling a choice which will provide both economic and effective circuit protection.

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E8610-2	Audio Analyser Display Driver	K
E8610-3	Audio Analyser Display	H
E8610-4	Audio Analyser Power Supply	F
E8611-1	Audio Switcher (2 bds)	H
E8611-2	PLL Frequency Meter (4 bds)	Q
E8611-3	Upgradeable Amp PSU	J
E8611-4	Call Meter, Main Board	O
E8611-5	Call Meter, Interface Board	N
E8612-1	Bongo Box	J
E8612-2	Biofeedback Monitor (Free PCB)	E
E8701-1	RGB Converter	F
E8701-2	Mains Controller	D
E8701-3	Flanger	H
E8701-4	Audio Selector Main Board	M
E8701-5	Audio Selector PSU	H
E8701-6	Tacho-Dwell	F
E8702-1	Ratemeter Main Board	K
E8702-2	Ratemeter Ranging Board	F
E8702-3	Photo Process Controller (3 bds)	O
E8702-4	LEDline Display Board (2 off)	K
E8702-5	LEDline PSU and Controller (2 bds)	G
E8703-1	Capacitometer	F
E8703-2	Geiger Counter	L
E8703-3	Credit Card Casino	E
E8704-1	BBC Micro MIDI Interface	L
E8704-2	ETIFaker Patch Box	H
E8705-3	MIDI Keyboard Keyswitch Boards (3 bds)	W
E8705-4	Batlite	C
E8705-5	Budget Power Meter	E
E8706-1	Hi-fi Power Meter	N
E8706-2	MIDI Keyboard CPU	U
E8706-3	MIDI Keyboard Front Panel	O
E8706-4	Flame Simulator	G
E8707-1	MIDI Keyboard PSU	H
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E8708-3	Rev Counter	F
E8708-4	Car Alarm	F
E8708-5	Knight Raider	J
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E8806-3	Virtuoso Power Amp Board	N
E8806-4	Virtuoso AOT Board	G
E8806-5	Metal Detector	E
E8806-6	Bicycle Dynamo Backup	D
E8807-1	Bar Code Lock (2 bds)	N
E8807-2	Analogue Computer Power Board	L
E8807-3	Bell Boy	F
E8807-4	Logic Probe	C
E8807-5	Updated FM Stereo Decoder	J
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E8808-1	Breath Rate Main Board	H
E8808-2	Breath Rate Switch Board	C
E8808-3	Telephone Recorder	D

PCBs

E9006-1 Dark Room Timer .... G
E9006-2 Telephone Extension Bell C
E9006-3 Telephone External Bell .... D
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E9006-5 Bug Spotter .... E

PCBs for the remaining projects are available from the companies listed in Buylines.

Use the form or a photocopy for your order. Please fill out all parts of the form. Make sure you use the board reference numbers. This not only identifies the board but also tells you when the project was published. The first two numbers are the year, the next two are the month.

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E8810-2	Peak Programme Meter (2bds)	N
E8810-4	TV-to-RGB Converter	E
E8810-5	Electron RGB Buffer	C
E8811-1	NiCd Charger	E
E8811-2	Chronoscope (3 bds)	P
E8811-3	Digital Transistor Tester	G
E8812-1	Doppler Speed Gun (2 bds)	K
E8812-2	Small Fry Mini Amp	D
E8812-3	Thermostat	E
E8812-4	Burglar Buster Free PCB	D
E8812-5	Burglar Buster Power/relay Board	E
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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
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E8907-4	Aerial Amplifier main board	E
E8907-5	Aerial Amplifier power supply	E
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E8909-2	Trembler movement detector	D
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E8910-2	MIDI Mapper	M
E8911-1	Smoke Alarm main board	F
E8911-2	Smoke Alarm power supply	F
E8911-3	Frequency Meter (3 boards)	O
E8911-4	Serial Logic Scope	L
E8912-1	Mains Failure Alarm	D
E8912-2	Surveilance PCB	D
E8912-3	Slide/Tape Synch	E
E8912-4	Pedal Power	L
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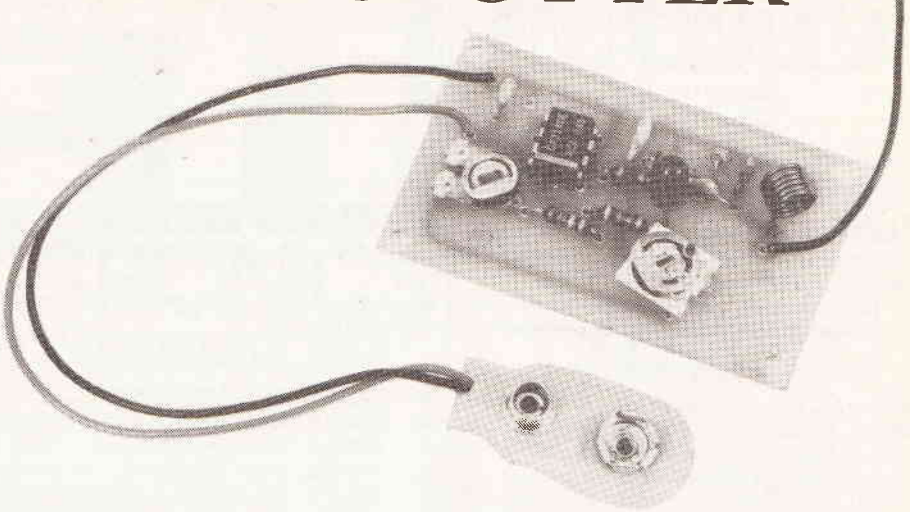
BUG SPOTTER



If you think you're under surveillance this one's for you. A Paul Benton design

So you think you've got something to hide? You think you're being bugged and you want to find out — then build the ETI Bug Spotter and you can tell 'em to bug off!

The project is simply a sensitive transmitter detector, capable of detecting transmitters of as little as 10mW or so over a distance of around 15 feet, making it an easy task to find bugs and deal with them accordingly.

A sensitivity control is included, enabling the operator with practice to pinpoint a hidden transmitter. Also, by a small modification, instead of the LED indicator a small meter may be connected. Although this doesn't necessarily upgrade the project's performance, it does make it look more technical!

Current requirements of the Bug Spotter are minimal, around 4mA on standby and 10mA when activated, therefore it may be powered from a 9V PP3 type battery for quite a while.

The whole project, with the exception of the meter if used, is mounted on a PCB measuring around 35 × 60mm, making it easy to fit into a small box.

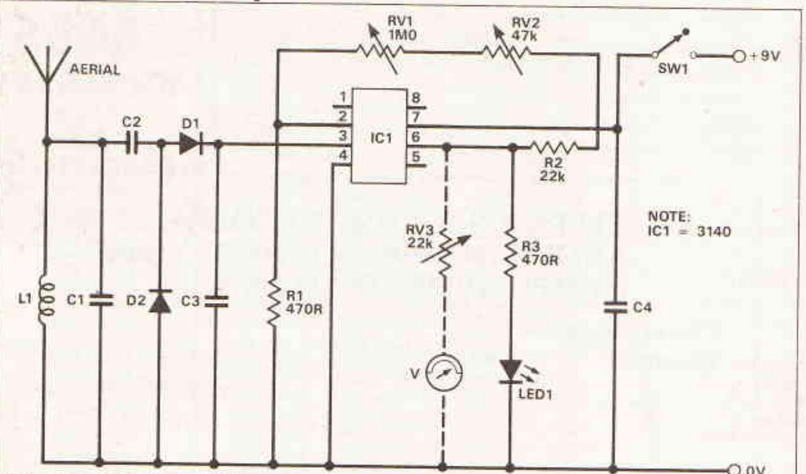


Fig. 1 Circuit of the ETI Bug Spotter

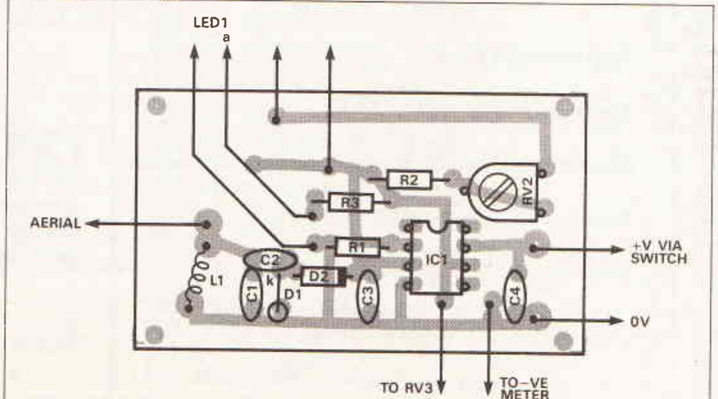


Fig. 2 Component overlay of the project

Construction

Figure 1 shows the circuit of the ETI Bug Spotter, while component overlay of the PCB is shown in Figure 2. The coil is made by carefully winding six turns of 24 gauge enamelled copper wire to a diameter of $\frac{3}{16}$ inch. Use a drill bit as a former. To ensure a good soldered joint, the ends of the wire must be scraped clean of all traces of the enamel, using a craft knife (be careful here) or abrasive paper. Make sure diode and IC polarities are followed. Otherwise construction is straightforward.

Although preset resistor RV2 may be omitted and a wire link inserted in its place, its function is described in the following section. The aerial may be a few feet of ordinary flexible insulated hook-up wire, but a telescopic sectional aerial may be preferred. In general, the longer the aerial, the better.

Testing And Use

After ensuring all components and wiring are correct, connect a battery to the project. If the variable feedback resistors are set at maximum resistance (RV2 set anti-clockwise, RV1 set clockwise) the Bug Spotter is now at full sensitivity. On this setting the LED may flicker on and off as the project is moved, perhaps for no apparent reason. It's necessary to carefully turn down the coarse control RV2 until random triggering ceases. This is best done in darkness: turn RV1 until the LED goes completely out, using RV2 as a fine control to get the LED just at the verge of coming on. Setting the LED on threshold prolongs battery life.

If readers prefer increased sensitivity at lower frequencies (say 27 to 50MHz) to pinpoint CB or 6 metre amateur transmissions and so on, soldering a 5.5 to 65p variable capacitor across the coil or increasing the number of turns of the coil will change bandwidth. If, on the other hand, coverage of the VHF/UHF spectrum is desired, removal of C1 and a few turns from the coil should do the trick.

Note that although the prototype features a preset as RV1, a panel mounting potentiometer fitted to the case with a pointer-style knob is preferable.

To use your project adopt a slow sweeping action and traverse the room slowly. If nothing registers do the same again keeping the aerial in a different plane. Note that most bugs have a vertical aerial — because car aerials are vertical! It's surprising what a difference it makes if the transmitter aerial and Bug Spotter aerial are oppositely polarised (say, one flat and one sticking up). In such conditions a bug can be as little as 12 inches away yet not register. Once the aerials are in the same plane, though, the LED seems to glow red hot! Be warned, patience and practice make perfect. Once a signal is found, and don't forget the bug may be 8 metres or more away, keep turning down the sensitivity until the transmitter is located.

HOW IT WORKS

Local radio signals are picked up by the aerial and fed to the tuned circuit, comprising coil L and capacitor C1, presenting a high impedance to the incoming signal. The signal is now fed through coupling capacitor C2 to the rectifier circuit D1 and D2. Resulting DC voltage is fed to the non-inverting input of IC1. IC output from pin 6 swings from virtually 0V to around 5V as a signal is detected, thereby supplying current to the LED and illuminating it.

Sensitivity of the circuit is governed by the amount of opamp feedback, and is therefore controlled by three resistors R2, RV1 and RV2. The larger the resistance between pins 2 and 6, the greater the gain. A word of warning however: If the resistance is increased more than that specified, interfering radiations such as mains hum will trigger the Bug Spotter.

If a meter readout is desired then a well-damped meter is recommended, as the project is handheld. As the sensitivity of the specified meter is 250μA full scale deflection, it needs a series resistance to allow it to be used with the full voltage swing output of the IC which may be up to around 5 volts. As a preset resistor is used for this purpose it should be obvious that even more sensitivity may be obtained by decreasing the value of the preset. Be warned, this may well result in wrapping the meter needle around its end stop if a strong signal is subsequently detected!

PARTS LIST

RESISTORS (all ¼W 5%)	
R1,3	470R
R2	22k
RV1	1M
RV2	47k miniature horizontal preset
RV3	22k miniature horizontal preset (optional)
CAPACITORS	
C1	5p6 ceramic
C2	330p ceramic
C3	1n ceramic
C4	100n ceramic
SEMICONDUCTORS	
IC1	3140
D1,2	0A90
LED1	Red LED
MISCELLANEOUS	
Meter	Maplin LB80B (optional)
PCB, battery clip, wire, insulated wire. Telescopic aerial (optional).	

BUYLINES

All parts are easily obtainable. You should have no problems. Mail order companies or local outlets will all be able to supply specified components or direct equivalents.

DARKROOM TIMER

John Linsley Hood describes a practical darkroom timer with some very useful functions.

One of the more useful electronic gadgets in the photographic darkroom is a circuit to switch on a photographic enlarger for a precise and reproducible length of time, and quite a number of circuits have been described, from time to time.

My re-involvement in this topic arose because a friend of mine had just brought himself a super new enlarger, and I had suggested, helpfully, that he might do himself a favour by pensioning off his old clockwork timer and get himself an electronic one. The old timer had to be mechanically rewound to the chosen time interval every time it was used. So I offered to build him one.

Now, most of the published circuits seem to have been designed by electronic engineers who are not themselves photographers, and in any case, were either rather primitive in their functioning, or were more complicated than I wished.

In particular, I wanted the time interval to be set by a rotary switch, with the intervals in an exponential series, such as 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, and 44 seconds, rather than a linear time scale controlled by a simple rotary potentiometer. The reason for this is two-fold. Firstly, one is possibly adjusting the time interval in the dark, or in the dim lighting, and it is easier to count clicks than to see a dial calibration. Secondly, linear scales are inappropriate for photographic exposure, where a one second change in time makes a big difference to a two second exposure, but has a negligible effect at say, 22 seconds.

The time-interval series I suggested above, being identical to the aperture stop series in a camera lens, has the characteristic that each increment, up or down, is equivalent in time to one half stop in exposure. So in the case of a monochrome or colour print, 16 seconds gives a print which is a bit light in tone, 22 seconds will give a small but noticeable increase in print density, and vice versa. This density increment will be the same for all of the adjacent time intervals.

A further useful feature, not found on the bulk of timer designs, commercial or DIY, is a switched 'safelight' output, so that the safelight will go off automatically when the enlarger is switched on, a useful feature when focussing.

Circuit design

For rather greater freedom in supply rail operation, coupled with a high input impedance to the RC timing circuit, a FET-input op amp was chosen, coupled to a bipolar transistor as a relay actuating system, rather than the CMOS 555 type of timer in the conventional circuit. A high gain op amp will switch over on a differential input voltage swing of a few millivolts, so giving a rapid on/off transition. The circuit used is shown in Fig. 1.

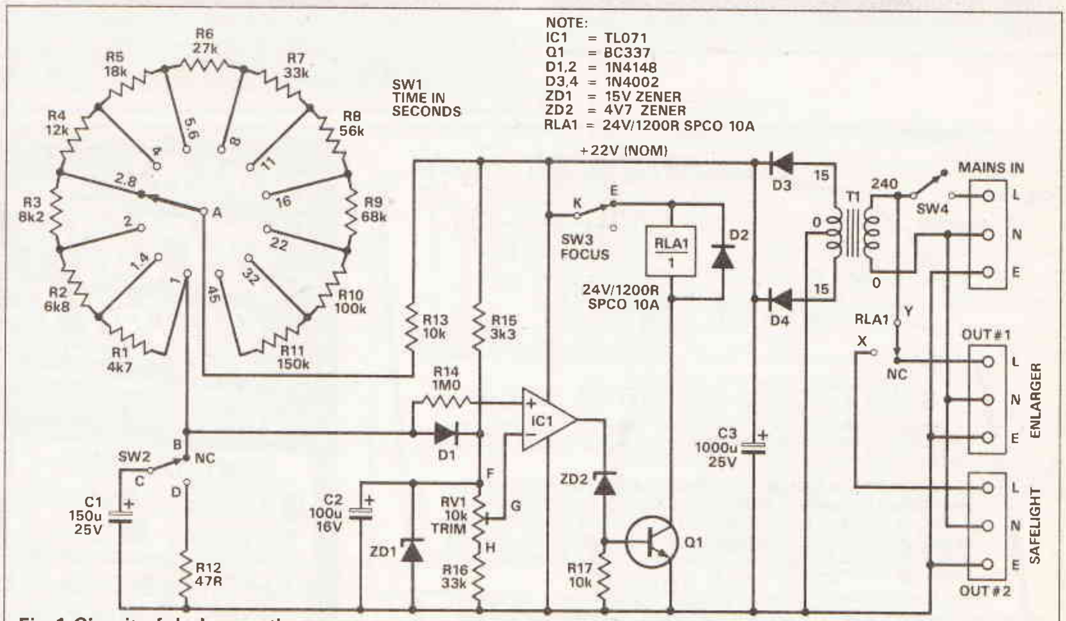


Fig 1 Circuit of darkroom timer

HOW IT WORKS

The timing interval is determined by the rate at which capacitor C1 charges through the switched resistor string, (R1-R11).

When the normally-closed 'reset' push-switch (SW2) is released, the non-inverting input of IC1 is taken to a potential of 0V, and its output falls to near zero volts, this cuts off Q1, and the normally energised relay (RLA1) drops out, switching the enlarger lamp on, and the safelight off.

C1 then charges up towards the +22V rail until the non-inverting input of IC1 exceeds the voltage on its other input, (adjustable by the 10k trim pot, (RV1)), when IC1 output swings +ve again, and Q1 is again turned on, actuating the relay, and switching off the enlarger lamp. D1 prevents the voltage on C1 and IC1 non− inverting input, from exceeding 16V. The TL071 has an internal output current limiting circuit of about 9mA which allows the simple zener diode coupling to Q1.

The precise time intervals given by the various switch settings on SW1 can be adjusted by the trim potentiometer firstly in the 16 second position and provided that C1 has a reasonably low leakage value, all the other settings should be reasonably accurate. SW3 switches the enlarger lamp on via the relay.

The whole unit was built in a plastic box which has fixing lugs to allow it to be mounted on the darkroom wall. C1 should be a good quality 25V working electrolytic capacitor to keep the timing as accurate as possible. Resistors R1-R11 are wired between the tags of the 12-way rotary switch SW1 for convenience. The total dissipation of the unit is less than 1W, so it remains very cool in use. The component overlay for the PCB layout is shown in Fig. 2.

PROJECT

PARTS LIST

RESISTORS (all ¼W metal film)	
R1	4k7
R2	6k8
R3	8k2
R4	12k
R5	18k
R6	27k
R7,16	33k
R8	56k
R9	68k
R10	100k
R11	150k
R12	47R
R13,17	10k
R14	1M
R15	3k3
RV1	10k preset
CAPACITORS	
C1	150µ/25V electrolytic
C2	100µ/16V electrolytic
C3	1000µ/25V electrolytic
SEMI CONDUCTORS	
IC1	TL071
Q1	BC337
D1,2	IN4148
D3,4	IN4002
ZD1	15V/400mW
ZD2	4V7/400mW
MISCELLANEOUS	
SW1	Single pole/12 way rotary
SW2	Single pole change over push switch
SW3	Single pole change over
SW4	SPST
TR1	15-0-15V secondary/3W PCB mounting
RLA1	24V-1200R SPCO 10A

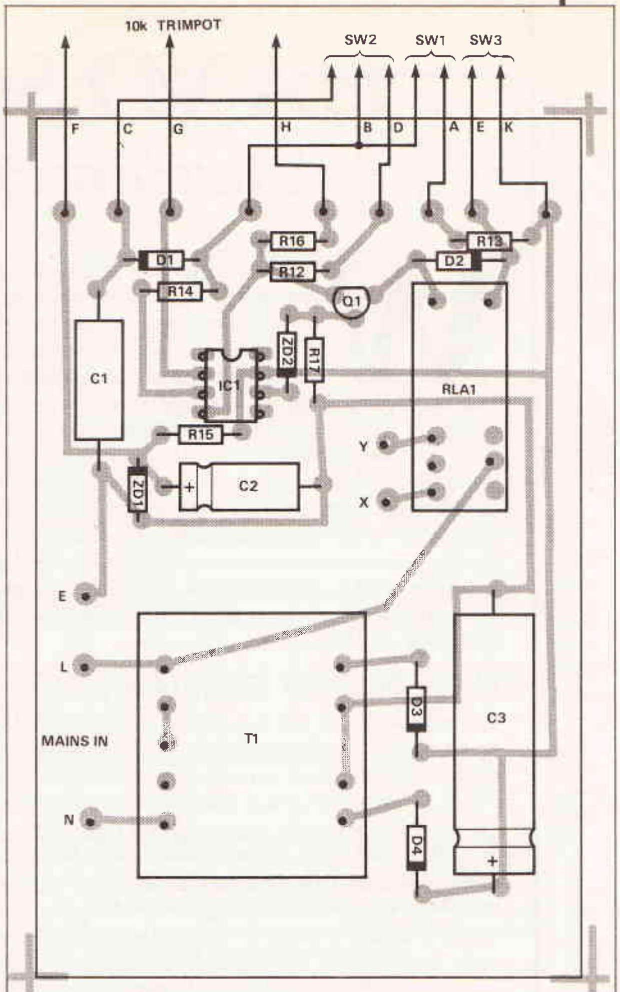


Fig.2 Component overlay of timer showing off-board connections

ETI

HAND SCANNERS

A Review Of The A4Scan

An increasing range of low cost scanners is now on the market. Andrew Armstrong reviews one of these, and the software used to drive it.

With the increasing popularity of desktop publishing for small personal computers, there has been an increasing incentive to provide an economical means to digitise small images, logos, and so on, to allow them to be printed as part of a desk top published document.

The professional way to do this is by using a flatbed laser scanner, with a resolution of perhaps 600 dpi (dots per inch) or better. This approach is far too expensive for the small business or the amateur, so the hand scanner was developed. Several companies produce hand scanners for use with IBM PCs and clones. They all work on similar principles, but the functions and features on offer vary.

Hand Scanner Technology

The normal hand scanner package consists of the scanner itself, looking something like a large and oddly shaped mouse, an interface card which fits a PC or AT expansion slot, and a disk of software to drive it. Most scanners have switched resolutions of 100/200/300/400 dpi, and a switch to select letter or photo mode. In letter mode, the scanner digitises images or text in terms of black and white. In photo mode, a dot dither pattern is applied to provide a grey scale by means of dot density variation, rather like image printing in a newspaper. Generally, more than one dot dither pattern is provided, and the user can experiment to find the one which best suits the image to be digitised.

The scanner itself uses an array of LEDs to illuminate the image to be digitised, and an array of charge coupled devices (ccds) to sense the image. To digitise an image, the scanner button is held down while the scanner is moved steadily over the page. A Roller on the base of the scanner drives a shaft encoder which detects the motion, and samples the output from the ccd array at even distances. At minimum resolution the scanner can digitise a strip about four inches wide, but the strip is narrowed if the resolution is switched to a higher level.

All the lower cost scanners work in monochrome, though there is at least one colour scanner available. This is more expensive, has lower resolution, and (of course) needs memory for its image files, but if you need colour then there is no choice.

Scanner Choice

I only have a black and white printer, so that a colour scanner would be of little use. I had wanted a scanner for some time and the incentive became stronger when I needed to digitise small diagrams for use in handbooks and datasheets. I went to the PC User show in late 1989 to look for a suitable scanner.

Several were on display. Some were being demonstrated to interested customers. Some were simply on show (*'Surely you don't actually want to see it work, sir?'*). All offered much the same facilities, and cost a shade under £200.

I almost missed the Supertech stand, because it was obscured by the crowd of people around it. Supertech distribute the A4Scan, sold with Image72 picture editing software. It offers the full range of facilities normally found on hand scanners including three switched dither patterns.

The demonstration was certainly impressive. Two identical scanners were on show, one being used for optical character recognition, and one to digitise images. The most impressive part of the demonstration was the ease with which images, once digitised, could be manipulated. A picture slightly too wide to scan in one strip was digitised in two strips, and put together into one coherent image on screen by means of simple mouse-driven manipulations. It was equally easy to flip, rotate, invert, or even make a negative of the image (like a photographic negative).

In Practice

The scanner was easy to install In my computer (a Tulip AT Compact 2), and was functioning after about 10 minutes. Though the scanner works in monochrome, the software allows you to add Colour to a

REVIEW

scanned monochrome image by image editing. However, the image files are larger, and less file storage formats are available, so I chose to use only black and white. The monochrome image editing software can save and load every image file format I have encountered to date, including widely used ones such as .IMG, .TIF, and .CUT.

At this stage, software compatibility problems appeared. All functions are selected by using the cursor to select icons on the left of the screen. However, when I started up the software, the cursor was confined to the top square of icons. Selecting and then cancelling a disk access function cleared the problem, and it did not recur until the software was reloaded. This is probably a BIOS compatibility problem, because a friend who brought the same model of scanner has no problem on his computer.

The scanning and image manipulation functions work almost as well in real life as in the demonstration. Line drawings, logos and the like digitise well. Photographs with a medium contrast range are also very suitable, though very low or high contrast ranges cause problems.

There are limits on what you can do. My desktop publishing software, Finesse 2.0, needs images to be in the .IMG format. There is a limit to the image area (approximately a quarter of the area available) which can be stored as a .IMG file, though I am not sure whether this is a limitation on the software buffer size, or on the file format. Complex image manipulations, such as rotate or slant, cause the computer to think very hard, and some resolution is lost. The image is very slightly elongated on the printout from my printer, which I suspect is an error in the 24-pin printer driver routine. Compressing the image vertically on screen to compensate for this is successful, but again some detail may be lost.

I was disappointed, but not very surprised, to find that other .IMG files, saved under GEM and nominally of a format compatible with the software, could not be edited. Attempts to load such files resulted in a picture rather like a television with a misadjusted line hold.

These snags are not serious, however. My scanner has done a lot of good work, of which two examples are shown here. The photograph was digitised in two strips for the proprietor of the local printed circuit board company, after he had failed to get acceptable results with his scanner. 'Good grief', he said, 'your scanner makes mine look like a toy'. The Image72 software also contributes to the high quality results. The digitised photograph is used on laser printed leaflets publicising the installation of a laser photoplotter.

The other example is of a graph used in the magazine *Ham Radio Today*. (Fig. 1). The original was hand drawn, and though accurate, it was unsuitable for publication. Postal delays had left no time for the technical artist to redraw it, so I digitised it in three strips, and spent just under two hours tidying it up, to produce the result shown. I am no artist, and could not have drawn it by hand to the required quality in that time. The text in the body of the graph was added by the image software.

Optical Character Recognition

I brought the optional OCR (optical character recognition) software with my scanner. This did not perform as impressively as the image manipulation, though it did work, and OCR is not easy. The OCR software includes its own scanning routine, and it is also supposed to be possible to save files in OCR format from the image scanning program. Following the instructions carefully, I could never get this to work. The stored image of the text always looked like a television with maladjusted line hold, just as when trying to read .IMG files stored by other software.

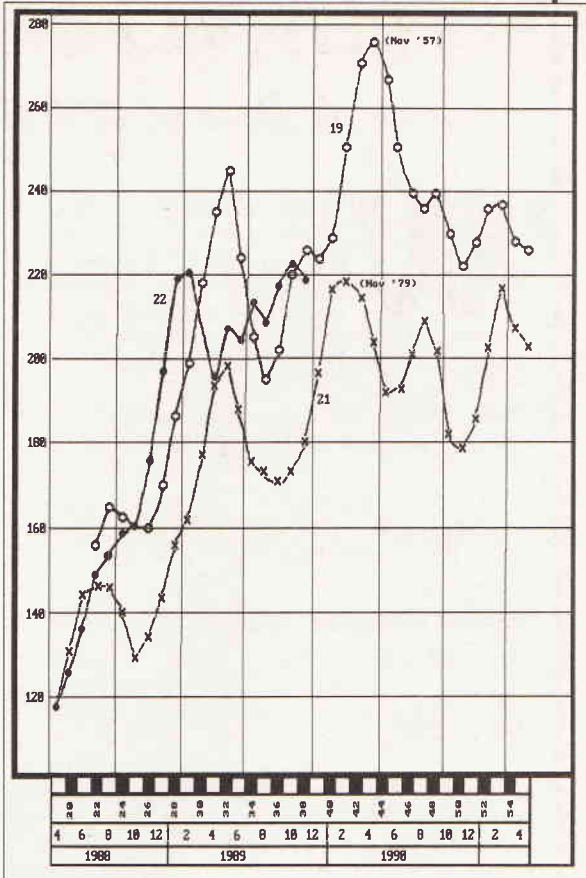


Fig. 1 A 'tidied' scan of hand drawn graph.

The OCR's own scanning routine allows only limited means of tidying up this picture, so that a very clean original is needed to give a clean enough image for OCR to work.

It is supposed to be possible to convert an A4 page to ASCII using this software, by scanning the page in strips and matching the edges on screen. In practice, this was very difficult, and would have been easier if the image scanning program's OCR save had worked correctly.

Two sample fonts are provided with the software, as well as sample OCR files to convert to ASCII. These worked very well, but it was difficult to achieve similar results with scanned text. There is a facility to learn new typefaces, and this even covers proportional spaced fonts (very unusual in low cost software). Some success was achieved using this function, but it could not be made to work quite well enough to be faster than retyping.

The user interface was a little unfriendly, and it was not always possible to back out of a mistake. I think, however, that relatively minor improvements in the overall software would make it much more useful.

The instruction books were written in a language somewhere between English and transliterated Chinese, but were usually comprehensible after a little thought. It would be nice, however, to see a proper English manual, with more explanation in some areas.

My overall assessment is that the image scanning system is good value and very useful, despite the snags. About the optional OCR, I am less certain.

You can contact Supertech Systems Ltd at: The Business Centre, Kay Street, Bury Lancs BL9 6BU. The A4Scan with OCR costs £199.95. (They are no longer sold separately).

2

NIKOLA TESLA

In the second of two articles George Pickworth describes Tesla's best known work, the Tesla Coil.

While Hertz's demonstration with sparks across the gap of his resonator comfirmed Maxwell's electromagnetic wave theory, Tesla gave a highly visual demonstration by lighting up a Geissler tube without the use of connecting wires. This Philadelphia demonstration of the *Tesla Coil,* during his 1893 address to the Franklin Institute of Philadelphia and the National Electric Light Association of St Louis, is considered by many as the first significant step towards realising the potential of Hertzian waves.

The system used by Tesla at that historic address was very similar to the syntonous spark radio system. It was later developed by Sir Oliver Lodge to become the standard system used until the invention of the triode valve in 1911, and spark transmitters continued to be used on ships until about 1935. The only real difference between Tesla's equipment and commercial spark radio sets is that Tesla used a Geissler tube as an indicator and a random length of wire as an antenna, while Marconi used headphones and a rectifier to give an audible signal.

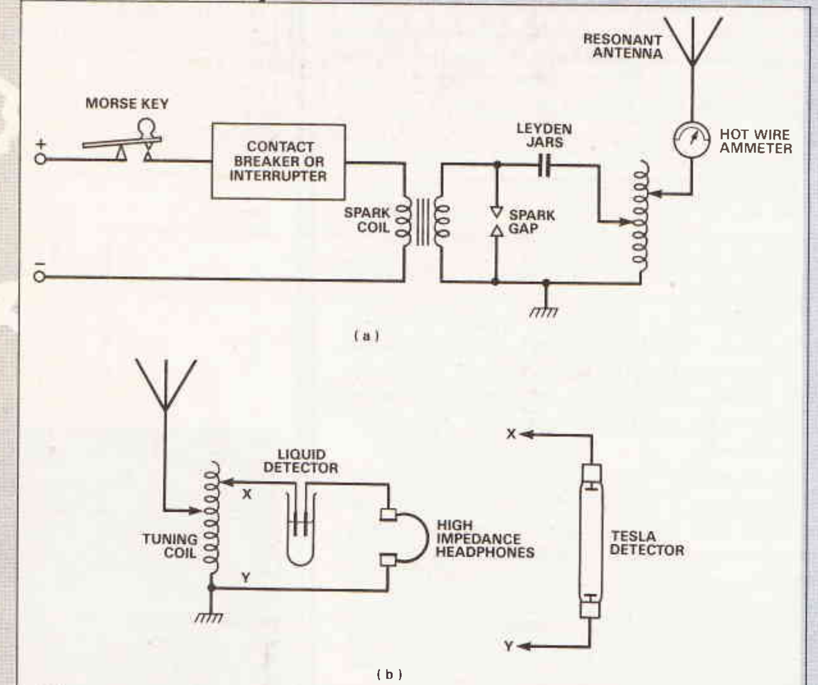


Fig. 1 A typical spark set (a) Transmitter (b) Receiver.

Early receivers used a wide range of rectifiers but the liquid type was most sensitive. Variable tuning capacitors were a later innovation. Tuning was done in early days simply by tapping the tuning coil (Fig. 1).

Tesla did not use a resonant wire antenna in his radio systems and so missed the opportunity to produce a commercial radio system before Marconi. Tesla developed what he called magnifying transmitters. These used enormous, high-frequency resonant transformers (the Tesla coil itself) and capacity type antennae, typically metal spheres on top of tall towers. However, like resonant antennae, the magnifying transmitters were energised at their resonant frequency and many of Tesla's techniques were 'copied' by later workers, including Marconi and Fessenden. However, whereas Tesla operated his magnifying transmitters at frequencies in the tens of kHz, Marconi used frequencies around 1.0MHz which allowed resonant antennae to be of practical size!

Experiments had shown that a waveguide between the earth and the ionosphere formed a good conducting path at frequencies between 3kHz and 30kHz, and this may be why Tesla neglected higher frequencies. Tesla believed that lower frequencies would not only provide reliable world-broadcasting, but make wireless transmission of electric power possible. Householders would extract electricity from the 'ether' using a simple rod antenna and a tuning device similar to a hat used for radio. Tesla first attempted to raise an antenna into this 'waveguide' by means of hydrogen-filled balloons. However, he later abandoned this approach in favour of terrestial installations using tall towers.

High Voltage

It seems that Tesla was convinced that capacity antennae would radiate power effectively at frequencies below 30kHz, provided that extremely high voltages were applied. Magnifying transmitters could generate millions of volts. He built many experimental magnifying transmitters in various sizes and configurations to provide data for the construction of very large installations.

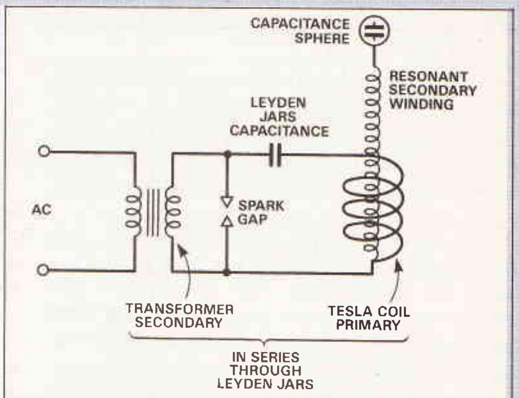


Fig. 2 Laboratory Type Spark-excited Tesla Coil.

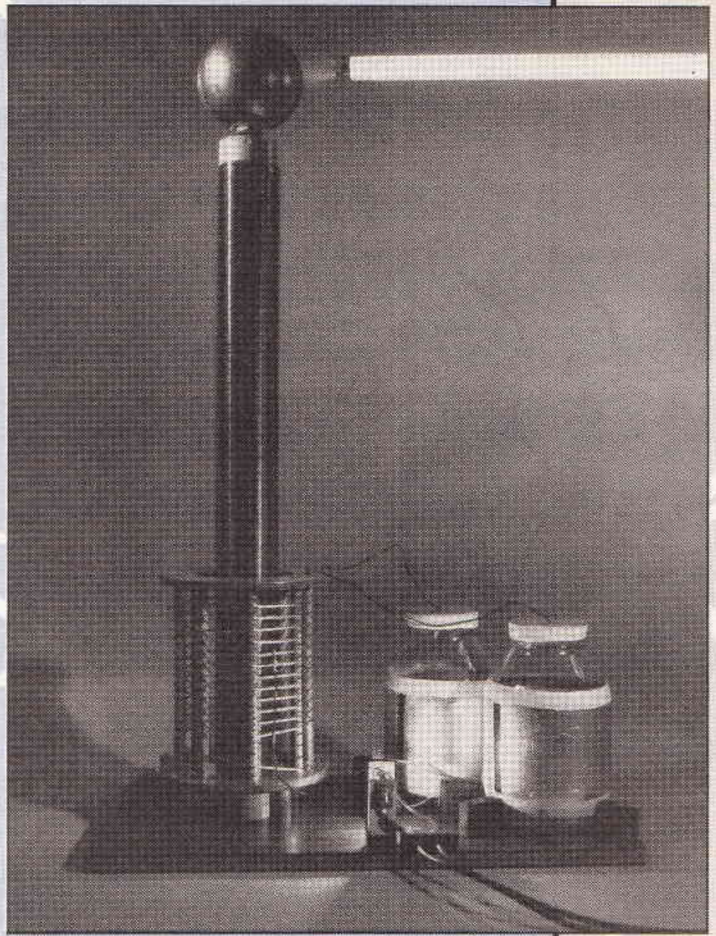
In 1899 the large 50kHz Colorado Springs magnifying transmitter and tower were completed. A slender, 145 foot tower rose above the wooden building which housed the actual transmitter. A 30 inch metal sphere on top served as a capacity antenna. The primary winding carried 1100A, so it is not surprising that the transmitter overloaded the Colorado power supply system and caused a black-out. This provided reporters with sensational copy about a mysterious force that Tesla had unleashed! (See Fig 3).

The Colorado magnifying transmitter undoubtedly gave spectacular displays of sparks and corona discharges that lit up the prairie sky and caused sparks across lightning arrestors 12 miles away. However, it is now known that capacity antennae are extremely inefficient at converting electric currents into electromagnetic (Hertzian) waves and most of the power was dissipated by coronary discharges. Whatever useful information the Colorado tower experiment had provided remains obsure, but Tesla predicted that the earth resonates at 6, 18 and 30Hz, and frequencies approaching the earth's resonance would be most effective for transmission of electric power.

Marconi used a spark transmitter which generated only a fraction of the power of the magnifying transmitter but operated at a higher frequency, and a simple but highly efficient resonant wire antenna, to send his first transatlantic signal. Despite this, Tesla planned even bigger magnifying transmitters designed to operate at frequencies between 3.0 and 30kHz. Work commenced on the ill-fated Wardenclyffe Tower on Long Island in 1901 but was abandoned in 1903. This installation was intended for world broadcasting and transmission of electric power across the Atlantic, and had a 250 foot tall tower with a 100 foot diameter hemisphere on top, but financier Morgan withdrew his support before the tower was finished.

By then it was apparent to backers and financiers that the future for broadcasting was with simpler transmitters, essentially the same as the devices used by Tesla but with resonant antenna systems. The magnifying transmitter was abandoned but smaller Tesla coils found many applications in laboratories where high voltages were required. Tesla's theory on VLF communication was proved basically correct but his dream of 'wireless' transmission of electric power never came to fruition. Having said that, projects to generate electric power in space and 'beam' it to earth now seem feasible.

The earliest practical application for Tesla coils was diathermy, advocated by Tesla before the turn of the century. In more recent years their principle role has become that of a high voltage line transformer in TV sets. The traditional Tesla coil still remains a classic scientific instrument.



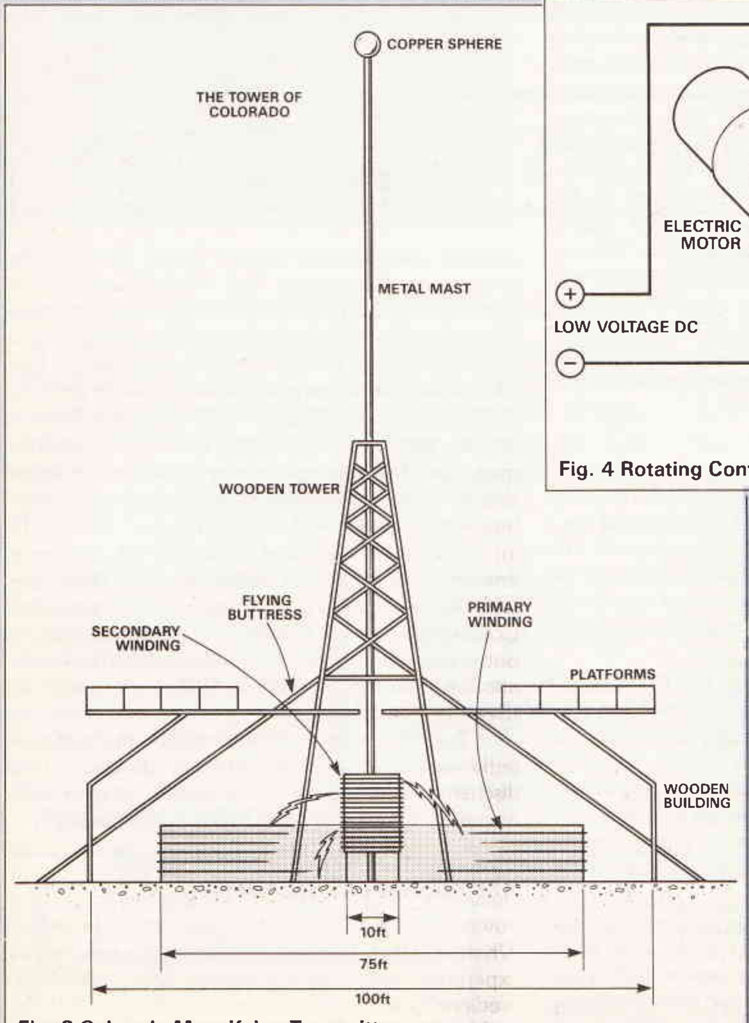


Fig. 3 Colorado Magnifying Transmitter.

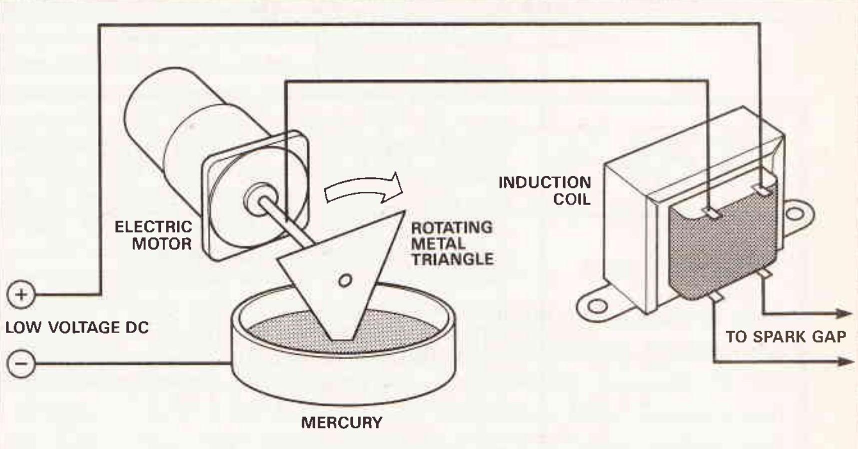


Fig. 4 Rotating Contact Breaker. (Readers are advised not to construct such a device).

◀At Colorado Tower laboratory Tesla tried a range of magnifying transmitters in various sizes and configurations. This one had a circular fence-like primary winding 75 feet in diameter and about 8 feet high. The secondary winding was about 10 feet in diameter and 10 feet long, and had 75 turns wound on a skeleton wooden frame. AC power was stepped up to 30kV by means of a transformer and the exciter operating frequency was 150kHz. Other types used 'circuit interrupters' to chop the current into pulses.

Excitation

Let's have a closer look at how the Tesla coil works. We'll start with the exciter, which delivers AC at the resonant frequency of the coil.

To all intents and purpose the parameters governing exciters for magnifying transmitters are the same as if the exciter were used directly as a radio transmitter. By the same token, a Tesla coil can be considered as a scaled down magnifying transmitter.

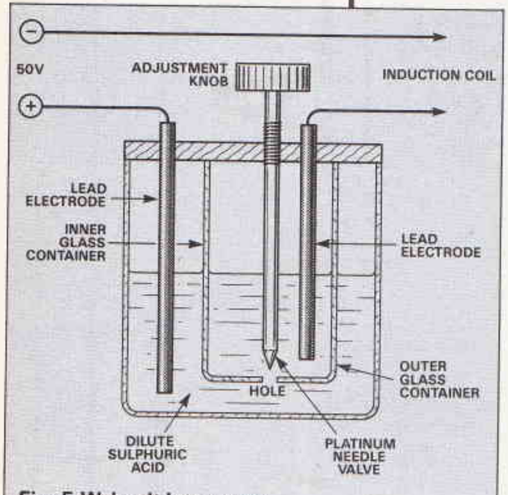


Fig. 5 Wehnelt Interrupter.

Almost any device capable of delivering sufficient AC at the resonant frequency of the magnifying transmitter can be used as an exciter. Experimental magnifying transmitters resonating at frequencies up to about 30kHz were excited directly by high frequency alternators. However this approach does not seem to have been applied to the very large magnifying transmitters.

At Colorado Springs, Tesla experimented with exciters using *circuit interrupters* that chopped the current into pulses. A large device with a 55 foot two turn primary winding was buried in the earth below the tower. The secondary winding, installed in the building beneath the tower, contained approximately 1.5km of wire.

The voltage developed across the secondary (high voltage) winding of a Tesla coil is a product of both the primary/secondary turns ratio and resonance. The resonant frequency is set by the number of turns of the secondary winding, capacitance between the turns, and the effect of a capacity hat (or the tower and sphere in the case of the magnifying transmitter). No capacitors are used and the winding therefore has a high inductance to capacitance ratio.

The primary winding does not have to be tuned when the Tesla coil is excited by high frequency alternators or pulsed DC as it is essentially an aperiodic coupling coil and can have very few turns, as in the case of the Colorado magnifying transmitter. On the other hand, spark type oscillator/exciters need a tuning coil, in which case the primary winding generally serves the dual role of exciter tuning coil and coupling coil. The tuning coil is effectively in series with the secondary winding through the capacitors. It therefore has a very small inductance as most of the inductance is provided by the spark transformer. (See Fig 2).

Radio Transmitters

With traditional spark radio transmitters, the antenna sets the operating frequency and is connected via a suitable tapping point directly to the tuning coil. The whole system is brought into resonance by varying the number of Leyden Jars and by means of taps on the tuning coil. Antenna current is indicated typically by a hot wire ammeter.

The transmitter used during the Philadelphia demonstration consisted of a 5.0kW oil-filled high voltage spark transformer, a spark gap, a bank of Leyden Jars and an induction coil to which an antenna wire was connected to run along the ceiling. At the other side of the stage was an identical bank of Leyden Jars, an inductor and antenna, but the spark gap and transformer was replaced by a Geissler tube.

While high powered spark transmitters used mains power and transformers to produce the spark voltage, smaller spark transmitters used induction coils operated from low voltage DC. The disadvantage of induction coils is that they need a high speed make/break device and its associated capacitor. The simplest and earliest make/break system used the magnetic field of the coil's own core in an arrangement similar to that of a buzzer. However, the closed period is longer than the open period to allow the magnetic flux to build up within the coil.

Improved results were obtained with independent contact breakers. While the buzzer principle was most widely used, another common device was a triangular piece of metal rotating at high speed, dipping into a trough of mercury. (See Fig 4).

Electrochemical devices were also used and the Wehnelt interrupter was the most simple. This allowed operation at frequencies up to several thousand Hertz, much higher than was possible with mechanical devices. While a high frequency make/break resulted in a stronger spark and better overall performance, it had no effect on the transmitter frequency. (See Fig 5).

The spark transmitter was unsuitable for telephony, so from about 1910 Professor Fessenden experimented with high speed interrupters which

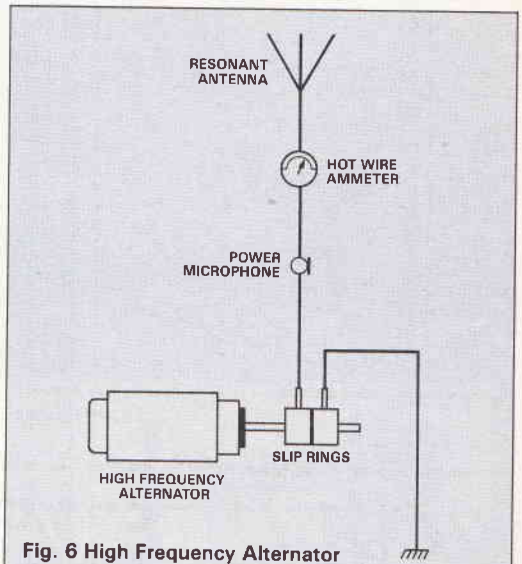


Fig. 6 High Frequency Alternator Telephony Transmitter.

directly energised the antenna. These were unsatisfactory as the system had inherent mechanical problems and arcing occurred across the contacts. Moreover the tone was very rough and could not be modulated with speech. On the other hand, high frequency alternators could be used directly for radio transmission by simply connecting the alternator to a resonant antenna. In its simplest form, tuning coils and capacitors were not required, and the sine waves could be modulated with speech signals by inserting a power microphone in the antenna lead. (See Fig 6).

Although Tesla had made 30kHz alternators before 1895, he did not capitalise on this technique. The best alternators had an upper frequency limited of less than 100kHz, requiring very long antenna, but the system was highly practicable and the Fessenden transmitter, operating at about 50kHz, was used in the USA for broadcasting before World War 1. During the war, a 200kW alternator transmitter was installed at the Marconi Worldwide Wireless Station at New Brunswick, New Jersey to replace the original high-power spark transmitter.

A Replica Of A Traditional Demonstration Tesla Coil

In the course of producing this article, I built a demonstration Tesla coil, keeping as close as possible to the coil used by Tesla during his 1891 to 1893 UK Lecture Tour.

A 240V to 10kV spark transformer was available and was used for the project. However, an induction coil and a Wehnelt interrupter, (Fig 5) could have been used to generate the spark current as this device is very efficient and easily made from plastic containers. The needle valve is not essential.

The spark gap consisted of two brass rods mounted on insulators to give an adjustable gap of 1/4 to 1/2 an inch, and is connected to the spark transformer by a car ignition cable. Commercial spark radio transmitters often used rotating spark gaps as they reduced erosion and gave a more pleasant note in the receiver. Very high power installations used sparks up to 14 inches in length.

The secondary (high voltage) winding, which sets the resonant frequency, consisted of 500 turns of 1.5mm armature wire. It is close wound so that the windings occupy about 750mm of a 900mm length of 70mm diameter plastic pipe. A 100mm diameter copper ballcock float was attached to the top and connected to the upper end of the winding while the lower end was connected to a large screw terminal. The capacity between the turns and the effect of the copper ball determines its resonance frequency. No capacitors were used.

The inductance of the coil was calculated using:

$$H\ (\mu H) = d^2\, n^2 / n18 + L40$$

where *d* is the diameter of coils in inches, *n* number of turns and *L* the length of the winding inches.

The secondary winding had an inductance of 1.7mH. As it is impractical to calculate or measure the self capacitance of the coil and the effect of the copper ball, this was estimated to be about 200pF, indicating that the resonant frequency would be about 300kHz. This was confirmed using a grid dip meter.

The 200mm diameter primary (exciter) winding, on the outside of the secondary, consisted of 12 turns, but normally only 6 turns are brought into the circuit; the optimum tap being found by experiment. As the calculated inductance of the primary winding was only 3.75μH, the balance of inductance necessary to make the exciter oscillate at 300kHz with 2n0 Leyden Jars was provided by the spark transformer in series with the Leyden Jars.

High voltage 2n0 capacitors are scarce and expensive and as the Tesla coil was to be as authentic as practical, a pair of replica Leyden Jars were used to tune the primary winding. They were made by coating the inner and outer surfaces of large glass pickle jars with aluminium foil. Their capacitance turned out to be almost exactly 1n0 each. (Fig 7).

Warning

Although this Tesla coil generates very high voltages, the current is low and should not present a serious hazard, nonetheless the spark current is derived directly from AC mains. Construction should only be attempted by those who have skill and experience with very high voltage equipment, as this Tesla coil is intended primarily for colleges and institutions.

Also the coil resonates at approximately 300kHz, so where there is any possibility of it causing radio interference, the device should only be operated in a room with a Faraday screen. However the coil does not seem to cause interference to television or FM broadcasts.

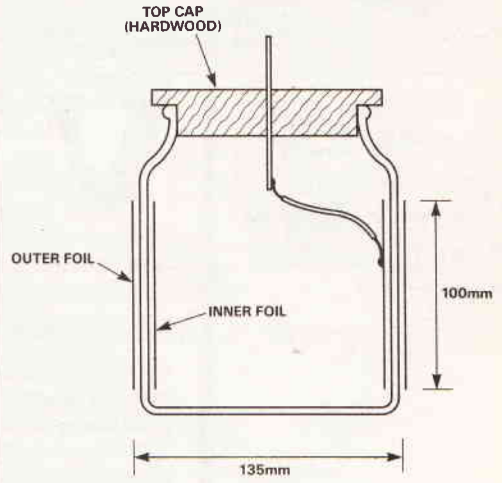


Fig. 7 Leyden Jar.

TESTING TESTING

Mike Barwise gives some methods for component testing, and starts looking at fault finding in real circuits.

Voltage measurement, described in ETI April 1990, is by far the most common use of multimeters, but they do have other uses. The obvious and common alternative functions are current and resistance, and many modern digital instruments also have various component test functions.

Measuring current

We'll first look at current measurement. Whereas when measuring voltage, the meter was connected in parallel with the circuit under test, to measure current directly, the meter must be placed in *series* with the circuit. This means that you must break the circuit to insert the meter. This is not always possible, particularly if you are taking measurements on a high density printed circuit board, but sometimes there is no other convenient way of taking current measurements.

When do we need to measure current in this way? As explained last month, you can determine a current flowing in a known resistor by measuring the voltage drop across it and applying Ohm's law. This works fine when:

1. You have a known resistor in the right place in the circuit under test (when designing your own circuits, you can build them in).
2. The value of the test resistor is very small compared with your volt meter resistance.
3. The current to be measured is fairly small.

When you must measure currents in the order of several amps derived from low voltage sources (less than about 50V), the value of the series test resistor must become extremely small to avoid unwanted voltage drops under normal working conditions. Such small test resistor values can lead to very large measurement errors if small amounts of stray resistance are not taken into account during measurement. Under these conditions, direct current metering using a series-connected meter is the best option. Once again, well designed circuits will have removable links for testing currents. Remember that the series current meter has a resistance of a fraction of one ohm, so it will be almost instantly destroyed by connecting it across a source of voltage. *Never do this!*

Measuring Resistance

Coming on to resistance measurement, there is one very big difference. Voltage and current measurements are essentially measurements of working conditions. Resistance measurement is really a kind of component test.

There are two main approaches to resistance measurement: either a constant voltage is applied across the component under test and the resulting current measured, or a constant current is passed through the component, and the resulting voltage drop is measured. Most modern digital meters use the latter method, while archetypal analogue meters such as the AVO 8 would measure the former. In either case, the voltages and currents involved are pretty small (to avoid component damage) and the metering system detects very small differences.

Because you are applying known conditions to the component under test it is very important that there are no other voltages or currents present. Resistance measurement is essentially made on components out of circuit.

A major source of error in measuring small resistances is the cumulative resistance of test leads, meter sockets, range select switch contacts and so on, generally referred to as stray resistance. All reasonable analogue resistance meters which work on the constant voltage principle, have a zero adjust to allow for the drop in voltage of the battery as it ages. This can, of course, also be used to null stray resistance. Very good digital resistance meters, working on the constant current basis, also have a null control for stray resistance. However, most of those under £150 don't. Allow for this by taking a preliminary reading with the test leads shorted together on the resistance range you are going to use, and then subtract this result from the result of your measurement.

For really accurate measurement of resistance, particularly of small values, a *bridge circuit* (Figure 1) is used. The fixed resistors are selected to a very close tolerance, and the variable resistor is equipped with a precisely calibrated scale. The bridge is effectively a pair of potential dividers in parallel, with a bipolar (centre zero) current meter connected between their midpoints. The difference between the voltages at the midpoints of the two potential dividers determines both the direction and the size of the current flowing through the meter connected between them. The unknown resistor (the component under test) is inserted into the bridge, and the variable resistor is adjusted until the meter indicates zero current flow. The two arms of the bridge are then exactly matched (the potential at both ends of the meter is the same), and as the two fixed resistors are equal, the variable and the unknown must also be equal, and the value of the unknown resistor can be read off the scale.

Commercial resistance bridges are available with precision in the order of ±0.5%, but they are very expensive. Older bridges can be picked up secondhand quite cheaply, but these tend to read to about ±1%, as they date from the days of general use 10%-20% resistors, when even 5% components cost the earth (late 1960s-early 1970s). These days, when 5% is the cheap standard component and 1% resistors at 0.3W only cost about 5p, the ordinary digital meter resistance range will serve for most purposes, as you very rarely need to select resistors to better than 1%.

Component Tests – Checking Diodes And Transistors

The analogue multimeter normally stops at voltage, current and resistance, but with the advent of compact microcontrollers, many digital meters perform a whole range of useful additions. The most common are

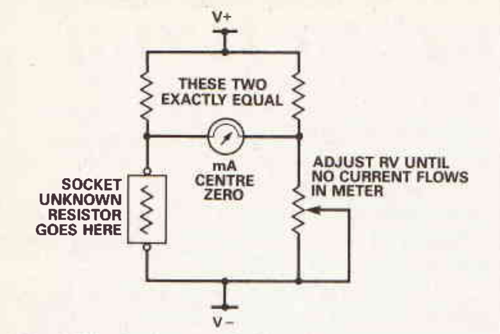


Fig. 1 The Resistance Bridge

diode test and transistor h_{FE}. These features are very nice if they happen to be on your meter, but you can get by without them by using your ingenuity. Let's see what they do.

First, the diode test. You plug in your diode in the forward biassed direction, and the meter passes a small constant current through it and gives you a value for its forward voltage. If you plug it in back to front, a good diode will give you an open circuit indication. By far the most useful part of this test is the check whether the diode is duff, indicated by open circuit or short circuit in both directions. The forward voltage of any diode is very dependent on both the diode current and temperature, and as you don't know what current the meter passes through it, the reading does not reflect the forward voltage in your circuit very well at all. The resistance ranges of your digital meter also use a constant current for measurement, so using the lowest resistance range will equally well verify whether the diode is good or blown, although the numerical reading in the display will not be meaningful.

The transistor h_{FE} test works in a similar way: a small constant base-emitter current is passed, and the normalised collector current is displayed. However, once again, provided you know what transistor you are dealing with (given by the type number), you are really interested in whether the transistor is functional. The makers' data sheet gives you the h_{FE} range (typically very wide, for example the BC184L has an h_{FE} of 250-850, and the TIP31A has an h_{FE} of 10-50), and you choose something in the right order. Thereafter most good transistor circuit design is founded in making the effects of h_{FE} spread as insignificant as possible by clever biasing and feedback, so that components do not have to be individually selected during circuit manufacture. The exact figure for a given device is thus not very important.

How do you tell whether a transistor is duff or not? Figures 2(a) and 2(b) show the theoretical 'diode equivalent' of NPN and PNP transistors by wiring up diodes (the common connection has to be one piece of silicon), but you *can* look for the virtual diodes with the low-resistance range of your digital meter. Either one may be open-circuit or short-circuit in a blown transistor. It pays of course, to test each 'diode' both in forward and reverse bias (by switching round the meter leads).

A final word of caution: you should not use an analogue meter with constant voltage resistance measurement for these semiconductor tests. Too much current would flow in small-signal devices, and you would probably destroy good semiconductors during the test. The current supplied by the digital meter (constant current test) is very small: a few μA.

A Real Problem

Now we get down to some real problems. We will look at a succession of genuine fault finding and measurement scenarios. In each case we will discuss the best choice of equipment and its most suitable application as fully as possible.

This month's circuit is a simple megaphone amplifier to be driven by a cheap dynamic (moving coil) microphone, and capable of delivering about 2W into a 4R load a 12V supply (Figure 3). It should work fine, but there is some fault or other in the individual on your bench, because it has been sent in for repair. Your job is to find the fault and correct it. This is the typical repair workshop scenario: you've never seen this amplifier before, but you must get it working by yesterday morning.

Your first task is to work out what the circuit *should* do. Then you can compare what it actually does with what you expect to find at the point where it is misbehaving. The report from the typical non-technical user just says 'does not work properly', so this does not help you.

Step one is to simplify the problem. Break the total circuit down into stages: sub-blocks with specific functions. You can then perform first-level tests at a much more general level: a big time saver.

Figure 3, shows that the circuits surrounding the first two transistors (Q1, Q2) are remarkably similar. Each consists of an input coupling capacitor, a base

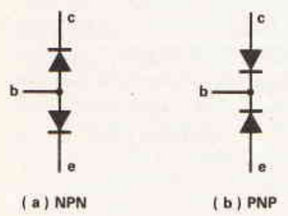


Fig. 2 'Diodes' within transistors

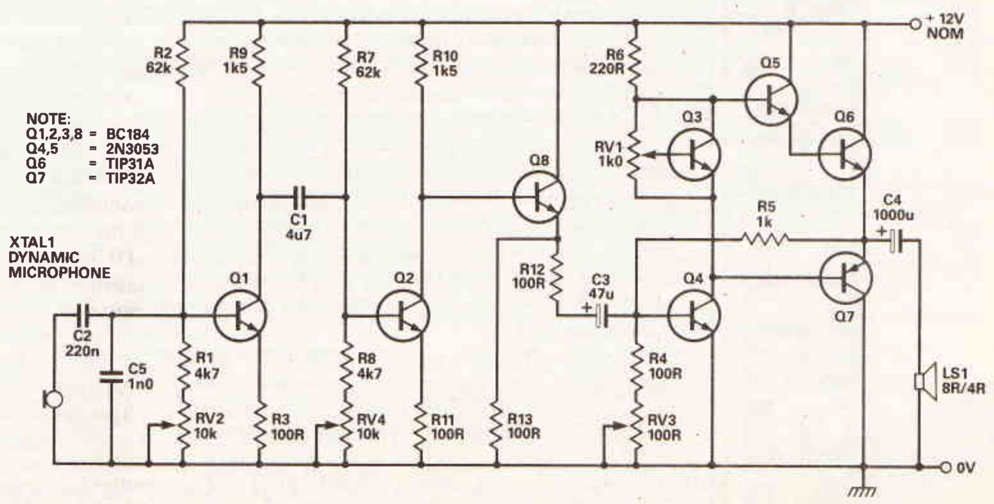


Fig. 3 Megaphone Amplifier Circuit

bias potential divider, an emitter feedback resistor and a collector load resistor. Each circuit is in fact a standard and basic common emitter amplifier with emitter feedback, and each constitutes a voltage gain stage of the amplifier circuit. The transistors are small low-wattage devices, which confirms the immediate expectation of small signals (a microphone input). You would expect the voltage gains of the two stages to multiply. The inter-stage capacitors isolate the input and output bias voltages (DC) from preceding and following circuits.

The next active component in line is another small transistor: Q8. This is wired as an emitter follower or voltage follower. It acts as a unity gain voltage amplifier and a current amplifier with a gain limited only by the inherent current gain (h_{FE}) of the transistor. This is part of the third stage, the driver, consisting of Q8, Q4, and associated passive components. Q8 is AC coupled to Q4 to prevent disruption of the base bias to Q4. The final stage of the amplifier is the output stage, consisting of Q3, Q5, Q6, Q7. This is what actually supplies the massive current to the loudspeaker.

You can now look in more detail at each stage in turn, to determine a set of testable values (voltages, because they're easy to measure) at various points in each stage. When you test the amplifier, you will look for these values to determine where they are off specification.

Start with the input stages. The voltage gain of each stage is defined by the ratio of the collector and emitter resistors. In this circuit, in both stages, the ratio is 15:1, resulting in a voltage gain of 15 per stage. As there is no dissociation of AC and DC signals (the emitter resistor is not bypassed by a capacitor) the AC and DC gain are both the same. The DC standing (quiescent) voltage on the transistor collector is normally assumed to be about half the supply rail voltage. This would allow equal positive and negative-going swings at the output of the stage (symmetrical clipping) for large output signals.

The collector voltage is arrived at by determining the emitter resistor drop and multiplying it by the ratio of the emitter and collector resistors. This works by Ohm's law and the assumption of the same current in both resistors (ignoring the base current), which is perfectly adequate for non-critical systems using high h_{FE} transistors.

The emitter resistor drop is always a nominal 0.7V less than the base voltage with respect to ground and you set up the base voltage by adjustment of the base bias potentiometer. In this case, with a gain of 15 and a supply of ±12V, for a collector voltage of ±6V we would need about 0.4W across the emitter resistor and 6V across the collector resistor. This leaves around 5.5V quiescent across the transistor (CE), and would theoretically allow a safe output swing of ±4.5V or so for large input signals.

You are obviously not interested in very large signals here: the microphone will deliver about 10mV peak-to-peak if you really shout. This will yield 150mV peak-to-peak at the output of the first stage, and a maximum of 2.25V peak-to-peak at the output of the second, which is about a quarter of what the system is capable of. An emitter voltage of 0.4V is about the minimum allowable, the normal limits being from 0.6V to around 3V.

Stability will suffer most from this low emitter voltage: the ideal emitter voltage should be large compared to V_{BE} to reduce the effects of temperature dependent change in V_{BE}. This low emitter voltage is forced on us in this circuit by the supply voltage and stage gain requirements but what is its upper limit? The maximal positive-going output voltage is about 1.2V more than quiescent at the second stage output, and as the two stages use indentical components, their set-up will be about the same. Supposing an emitter voltage of ±0.6V, the quiescent voltage across the collector resistor will be around ±9V resulting in about ±3V at the collector with respect to ground. This leaves around 2.4V across the transistor (CE), which on maximal negative-going cycles will drop to about 1.2V. This is about the bottom limit in any conventional silicon transistor in this circuit (the lowest voltage drop you can get: the transistor will never be turned fully ON or in saturation).

There is one point to note: although the stage gains are both 15, giving a theoretical total of 225, the total real AC voltage gain of the pre-amplifier (stages one and two combined) measured at the output end of R12 is a bit less than this. You would expect a figure of around 180 in fact. This is because R9, R8 and VR4 form a potential divider via C1 for AC signals, which effectively reduces the output signal by about 20%.

So, to sum up on the voltage pre-amplifier: in a correct setup we should find an emitter voltage in the range of 0.4V to 0.6V and a collector resistor drop of about 6V to 9V. Centre points, say, of V_E 0.5V and V_{RC} 7.5V, both with a ±20% tolerance, which result in a comparatively large spread in V_C at 3V to 6V. Output clipping of negative-going cycles will onset at input signals greater than 10mV peak-to-peak for higher emitter bias levels than 0.4V. Overall AC voltage gain should be around 180.

The driver and output stages must be considered as one unit, due to the feedback from output to input via R5. Working conditions are as follows: Q4 must have a base voltage of about ±0.7V with respect to ground, as this is its inherent V_{BE} and its emitter is connected to ground. This 0.7V must therefore be impressed across the resistance formed by R4 and VR3 in series, the current supply for which comes from the output via R5. The same current must therefore flow in R5 as in the base resistance of Q4 (R4, VR3) so the voltage drop across R5 must be 0.7V multiplied by the ratio of R4+VR3 to R5. At the output of our driver stage we want the quiescent voltage to be midway between the supply rails (for maximal output voltage swing in both directions). This is ±6V for a ±12V supply rail. As the output end of R5 rests at ±6V, and as (R4, VR3) drops 0.7V, there must be about 5.3V quiescent across R5. Under these conditions, both Q6 and Q7 should just be conducting.

The quiescent current through them is set by adjusting VR1 to provide a variable stand-off voltage across Q3 between the bases of Q6 and Q7. This setup can be used for thermal compensation. The V_{BE} of Q6, Q7 and Q3 drop all with temperature rise, so the ratio between them stays roughly the same if all three transistors are at the same temperature. You will find them all bolted to the same heatsink under normal circumstances.

Q8 is an emitter-follower current amplifier. It provides a unity gain voltage output which follows the collector of Q2, but with a massive increase in current availability. This is the same as saying it has a very high input impedance and a very low output impedance. Although in principle, Q2 could provide enough current to supply the base of the driver (Q4), Q8 is needed because otherwise the Q4 base resistor of about 160R would work with R10 (1k5) as a potential divider on the output of Q2. This would reduce our hard-earned voltage gain by a factor of around 10. This would nullify the effect of the second pre-amp stage and give an overall gain of around 12. As it is, from the point of view of the collector of Q2, Q8 looks like very high value resistor in the lower half of the potential divider, so the output signal is not appreciably attenuated. C3 obviously isolates the bias voltage of Q4 base from the quiescent voltage of Q2 collector.

At first, it looks odd that the upper (NPN) transistor of the output push-pull pair (Q6) is driven in Darlington configuration with Q5, and the lower transistor (PNP) Q7 is not. The Darlington is obviously a means of enhancing the drive current to a transistor with very low h_{FE} (TIP31 h_{FE} 10-50). Q7 (TIP32) is a matched complementary transistor with the same range of h_{FE}, so why doesn't it need a Darlington drive as well? The answer is, it's got one. Q6 conducts on positive-going half cycles, and requires a source of current into its base (base more positive than emitter) which it gets via Q5 and R6 from the positive supply rail. Q7 conducts on negative-going half cycles and requires a sink of current out of its base (base more negative than emitter) which it gets via Q4 the driver transistor. Q4 thus acts as the Darlington comrade of Q7. Neat isn't it? Saves us a transistor!

Summing up on our power stage: there should be ±0.7V with respect to ground on the base of Q4, +6V at the emitter junction of Q6, Q7, and between about 1V and 1.2V between the bases of Q5 and Q7. The last components to note are C4, which blocks the otherwise heavy DC current from the emitters of Q6, Q7 (at +6V) to ground through the load, and C5, which acts as a bandwidth limiter for high frequencies by shorting them to ground before they get amplified. The system bandwidth limits are therefore defined at the low end by the ratio of stage input capacitor reactance to stage input impedance. The stage input impedance is more or less the resistance of the upper and lower resistors of the base bias potential divider in parallel. At the frequency where the capacitor has a reactance equal to the stage input impedance, the signal will be −6dB. The upper limit of bandwidth is defined by the ratio of C5 reactance to the sum of R1, VR2. When both are equal, the input signal will be −6dB.

Now you know what to look for, you can start testing the amplifier. First, you need to check whether anything is catastrophically blown up. The input should be shorted to ground to eliminate stray pickup (it's OK because the input is AC coupled!), and the power supply connected. *With no output load,* the power is switched on. If your power supply has a current meter, watch it like a hawk! If not, put a finger across the power transistors and keep your nose in shape. If, within no more than 15 seconds, you smell something hot, or your finger feels warm switch the power off. There is a major short circuit somewhere, and you cannot test the amplifier any further under power. Let's assume this test proves good. The amplifier draws a current of around 10 to 15mA and nothing gets hot. The next step uses the digital multimeter to check for the DC potentials we worked out. You can't use the AVO 8 here. Although it has adequate resolution, it has a resistance of 20kΩ on the range needed to measure the pre-amp transistor base potentials. This would spoil the readings as it would be in parallel with about 10k (for example, R1+VR2). We must work from the input forwards to the output, and remember that the figures we calculated are approximate. Tolerances of up to ±20% are quite likely, so we are working to less than 2 significant digits. Don't take too much notice of the least significant digits when using the digital meter. Of course, all your readings should be rigorously recorded. *Make no adjustments now.* Just record what you find. One of the best ways is to write the values in on a copy of the circuit diagram. This will take a bit of time, so I will leave you doing it until next month, when we will examine the results and consider what is wrong with the amplifier.

OOPS!

Quad Power Supply (April 1990)
In the parts list, IC2 should be 7905 and IC 4 should be 7912.

Oscilloscope (February 1990)
TS2 should have 550 turns, giving 110V rms.

Motorcycle Intercom (January 1990)
D1-D12 should be IN4148.

Wavemaker FG (January 1990)
R24 (82k) should be shown instead of the wire link below R29 on the Component Overlay (Fig 2). R9 on the Circuit Diagram (Fig 1) should be R31, and should be connected to the −12V rail. The resistor connected to IC2a pin 4 on Fig 1 should be R9.

And some we've printed before . . .

Navigate (April 1990)
Fig. 1a Maximum/minimum signal captions should be reversed.

Oscilloscope (February 1990)
Fig. 3. does not show the polarity of diodes D105,6. The cathodes point up the page. Diodes D304 is a 1N4148. Capacitors in the deflection amplifiers parts list are incorrectly numbered and should be C205, 206, 213 and not C105, 106, 113.

Text refers to inductors L203, 204; these should be L201, 202. Inductors L101, 102, 201, 202 are wound on 100k 0.5W resistors. The value of R201 should be 820R. The PCB track connecting RV301 to R313 should be extended to the pad of link 17. The foil on page 60, for the motherboard is at 95% of full scale.

Eprom Emulator (February 1990)
Under the construction heading, the bracket should include and read: so for example the $0000-$1FFF and $8000-$9FFF blocks are an illegal pair. The 18th line should read: If you are thinking of using non adjacent blocks. Fig. 5. shows a label LK9, it should be LK3.

Motorcycle Intercom (January 1990)
On the circuit diagram, R2 and R6 should be 100k, not 100R. Pins 1 & 5 of IC1 should not be connected to earth. Pin 2 should be connected directly to the junction of R2 & 3 — not to earth too. Capacitor C10 should be an electrolytic with positive uppermost. Junction of R39 & 20 should be labelled ½Vcc. All references to 0V5 should read ½Vcc. On the PCB overlay, R2 and R6 should be transposed. Similarly, R8 & 9 should be transposed.

Low Voltage Alarm (January 1990)
Resistor R1, shown in the circuit diagram as 1k0, should be 4k7 as in the Parts List. Pins 9 & 11 of IC1 on the PCB should be linked. This is incorporated in PCBs from the ETI PCB Service.

Virtuoso Power Amplifier (November 1989)
In the circuit diagram: the base of Q49 should go to R46, and not R47. Bases of Q45, 43 should be connected. R44 should be 220k.

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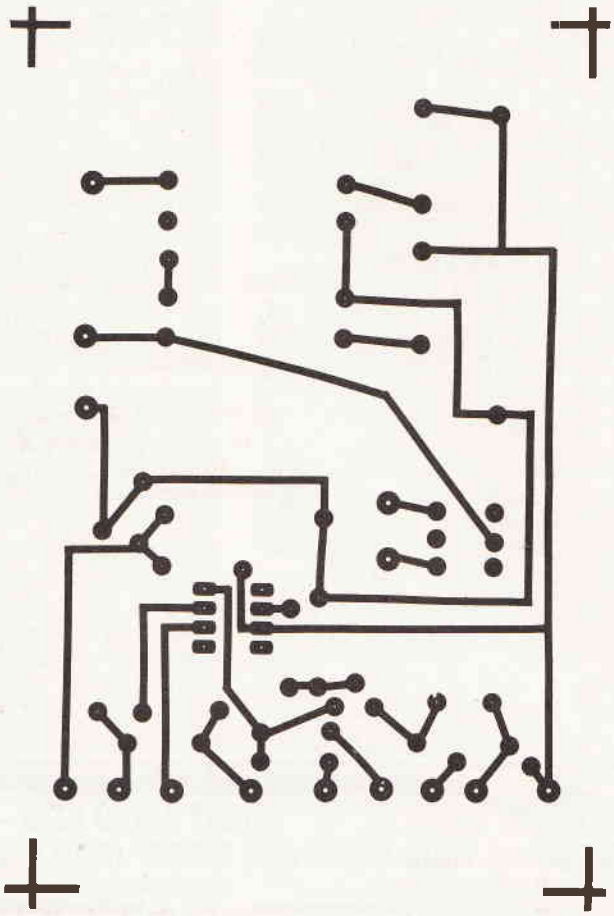

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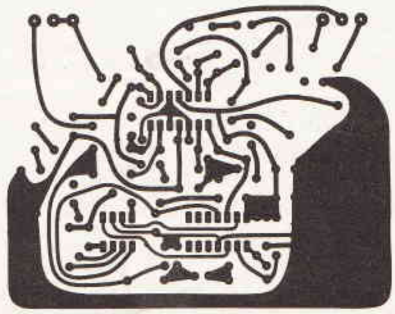

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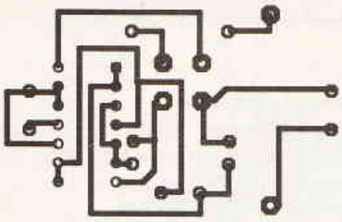

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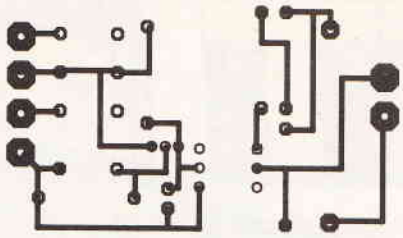

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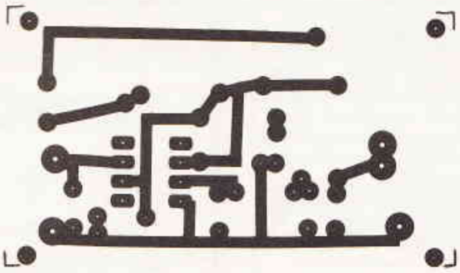
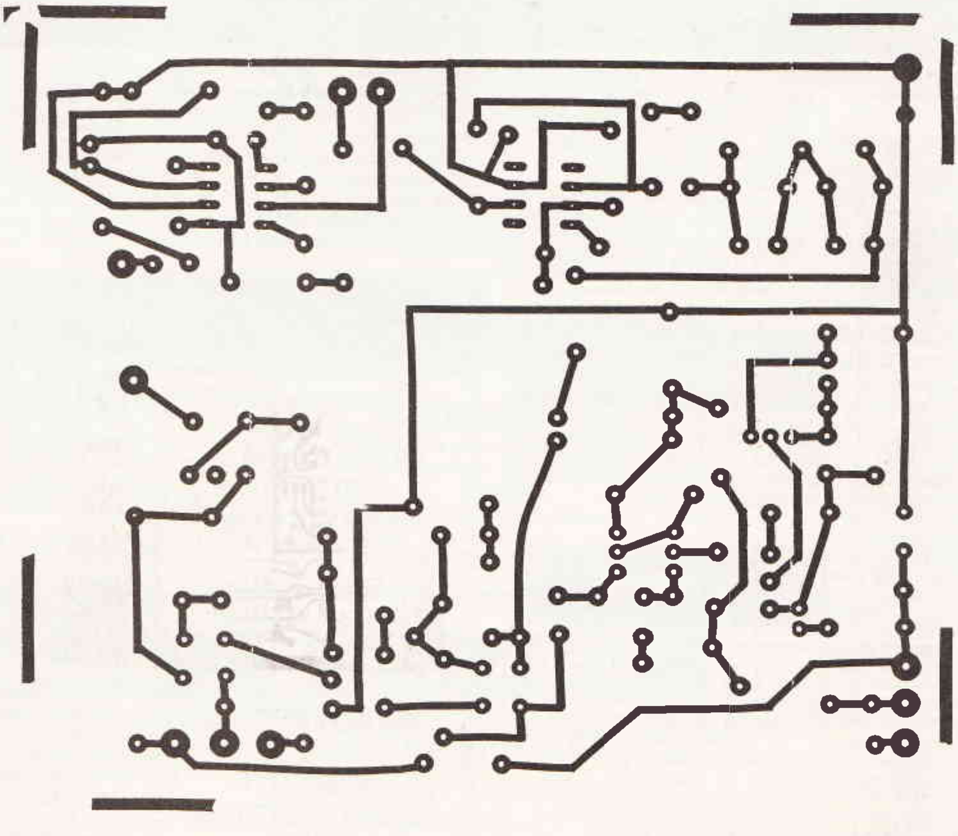


Bug Spotter



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NEXT MONTH

Next month, we've got a whole lot of interesting projects for you. We've got a guitar headphone amp to let you practice without disturbing everbody else in the house, and a new digital frequency meter. And if you have problems making difficult decisions, then our Decision Maker project may be just what you're looking for.

We'll be continuing our series on testing with some more about solving real problems, and a project to build a transistor tester. We'll also be featuring the second part of our series on the functions and uses of diodes, and we'll be looking at the problem of extracting signals from noise.

Could wind farms become features of our landscape? In the July issue, we take a look at the technology and practical implications of harvesting wind energy.

Our Audio section will bring you the latest news and reviews of audio technology, and we also review the Tsien Board Maker, the computerised PCB design system..

Don't miss the July issue of ETI. The magazine will be on the streets from 1st June.

The above articles are in preparation but circumstances may prevent publication

LAST MONTH

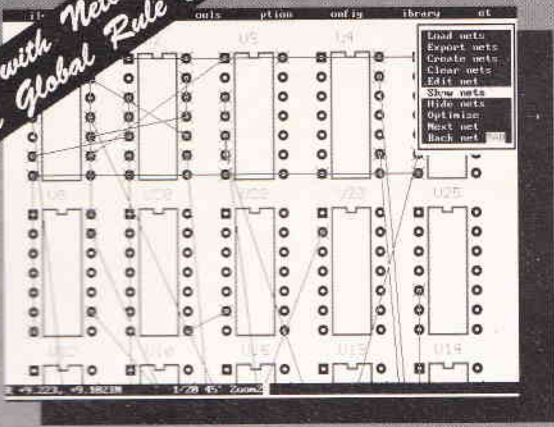
In May, we launched our new audio section, and full colour centre pages. We completed the Business Bass Amp, and eatured a project for a compact active speaker. We investigated a system for cutting fuel bills in commercial buildings, and presented a project for cutting phone bills. We gave you the final part of our series on radio, and reviewed two graphic equalisers. We also looked at the political and economic future of cable TV, and at how to take out one patent for several European countries.

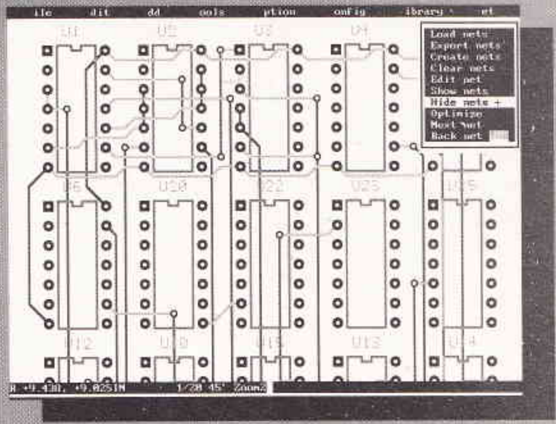
If you missed the May issue, a limited number of back copies are available from Select Subscriptions (address on contents page).

ADVERTISERS' INDEX

Now with Netlist capability and Global Rule Checking

BOARDMAKER 2 from TSIEN





BOARDMAKER 2 can help you turn a Netlist into a PCB that's right first time, quickly and easily.

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Feature Summary

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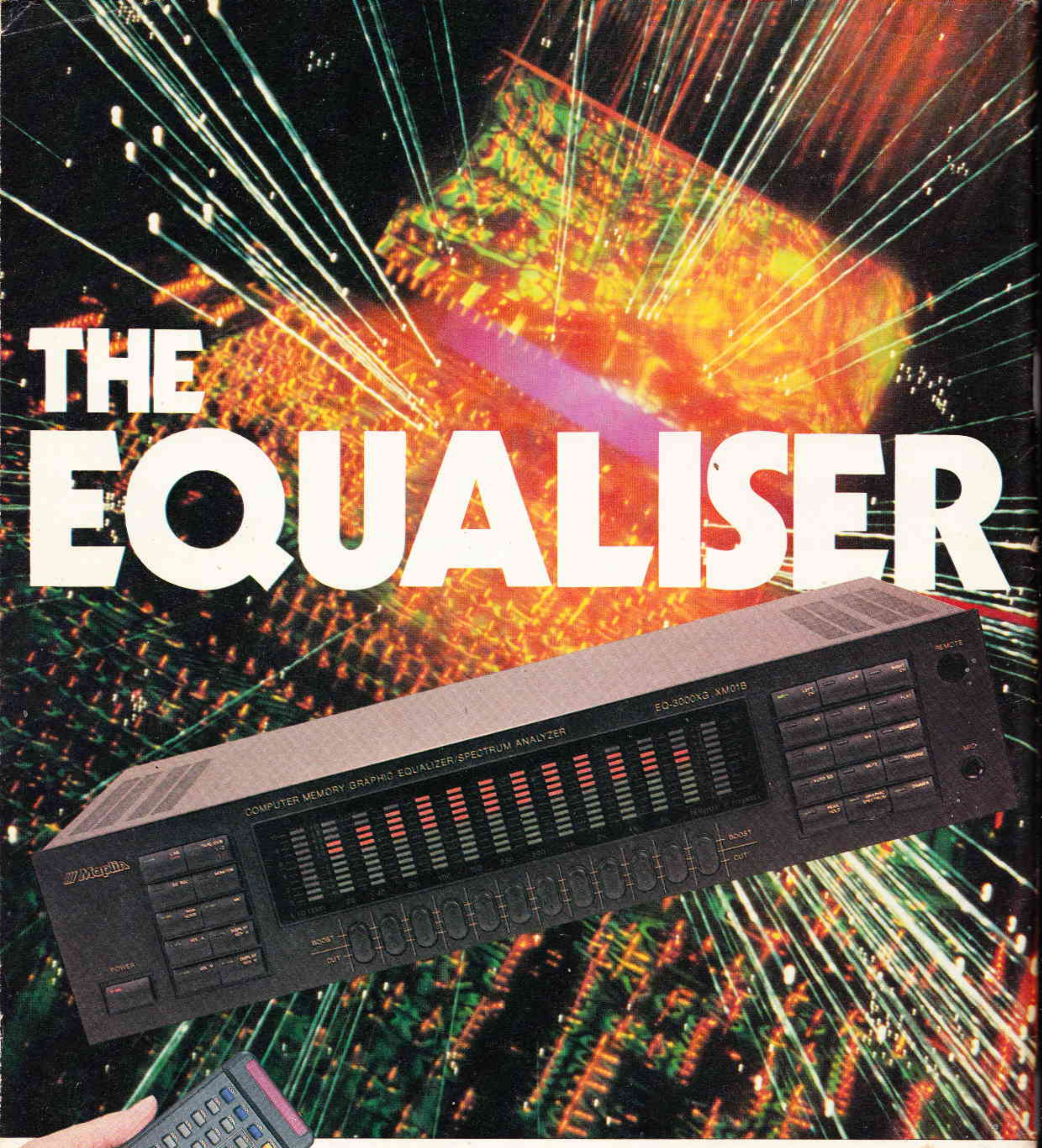

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