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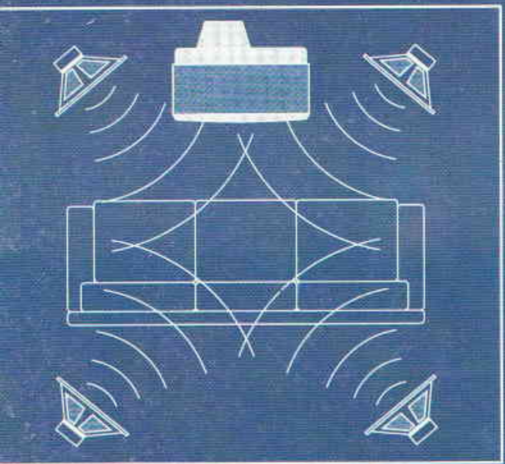

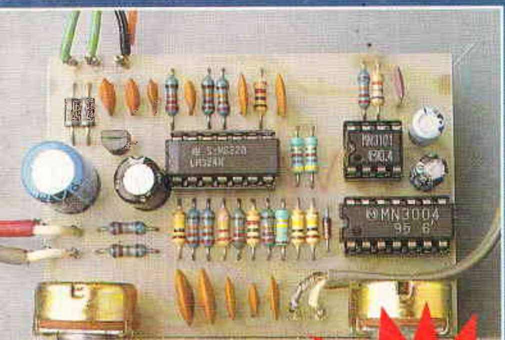

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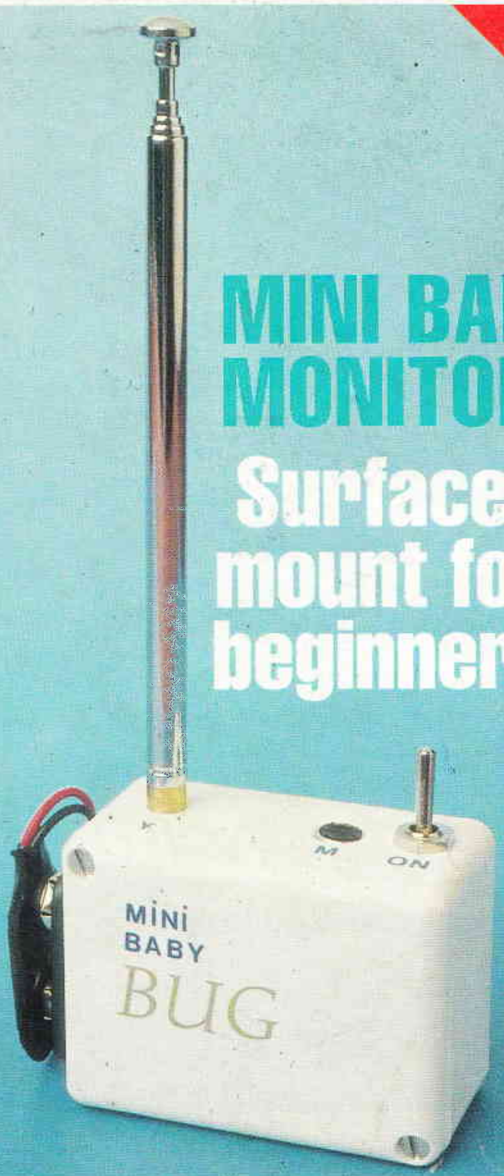

Surface-mount for beginners

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CONCEPTS IN OPTICAL CONNECTIVITY

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ULTRA-SONIC AUDIO SENDER

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AN ARGUS SPECIALIST PUBLICATION

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July 1992

Features & Projects

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Regulars

Editorial

By Paul Freeman

Computer speed of operation has been on the increase ever since the first electronic types appeared. Changes to the semiconductor type, substrait depth, capacity and inductive effects and frequency of operation are some areas which have all been altered to get information from point A to point B in the quickest time possible. Some say we are approaching the speed limit for existing technologies.

A light at the end of the tunnel

The ultimate would be to have a computer operating at the speed of light. The idea of using optical computation is not new. Light operated logic gates have been researched for some time but light interconnectivity is the emerging technology for the 1990s. In New Concepts in Optical Connectivity within this issue, Douglas Clarkson reports on the latest developments in this field being investigated at Kings College, London. First areas to be modified could be the replacement of copper interconnecting wires between boards with light guide.

Once the principles of controlled Photonic mechanisms have been established, there would seem no reason why other parts of the electromagnetic spectrum couldn't be used to perform the same job. They would have to use a different transmission guide material transparent to those frequencies and be radiation resistant. Might we see X or Gamma photonic computers in the future? Afterall, they have higher energy per photon and low diffractive effects.

Paul Freeman

OPEN CHANNEL

While it's just a small part of the telecommunications industry, radiopaging is a complete microcosm of the whole. By looking at the radiopaging concept, and the way it's going, it's possible to get an understanding of all things in electronics communication areas.

Long ago, radiopaging began as a method of communicating with doctors, in a London hospital. The hospital itself realised the need to be able to get doctors to respond when an emergency happened. If such a system could be performed by radio, doctors simply need to carry round a small radio receiver in their pockets, then when required an operator could simply 'bleep' them.

This first system used a simple loop of cable around the hospital, and transmitted at an almost unbelievably low frequency of 35kHz. Since then things have moved along apace. Such local area systems still exist — you'll still see doctors with 'bleepers' in their top pockets (still made by the same company, incidentally, who built the first system; Multitone) — but they work in considerably more complicated ways. Loop-paging systems are no longer used (even though you can often see, to this day, the remnants of the wire cable loops around the outside walls of many older hospitals). Instead, local-area systems use a more conventional transmitter and aerial, and a coding system that allows many hundreds of different bleepers to be used and accessed individually within the area. Teams of receivers can be grouped and automatically bleeped so that, say, if an emergency arises where a patient requires a particular group of doctors, nurses and support staff, the operator merely has to enter the team code number and all those receivers will be initiated.

From local-area systems things progress to wide-area systems, operating over large sites, say city-wide or county-wide. Coding systems are necessarily more complicated, as more and more users are incorporated into these systems. Soon, you need a national system — so that anyone travelling anywhere in the country can be paged. And I mean anywhere — I remember when the UK's system was first set up some 10 years back, trialing a receiver on an intercity-125 train out of St Pancras heading north from London. While the main transmitter was (and still is, I suppose) located on the Post Office tower, the receiver had no problems in picking up the signal on the train, at all times.

From a national system, we obviously need a European system, and from there a world-wide network. Or do we? Recently, there are moves to go to a satellite system allowing a pan-European network to commence. From here, I guess, the sky's the limit.

So you see, radiopaging effectively mirrors what's happening all over the telecommunications industry. From grass-roots startup systems, through bigger and bigger systems which incorporate more and more users, to world-wide networks allowing access to many millions of people. Virtually all communications networks follow this route. From little acorns...

But is this sort of progression really necessary? Do we need larger and larger systems? Or would smaller systems do the job adequately? Are we making mountains out of molehills?

All I'm saying is that systems controllers should checkout first whether users want such systems. Otherwise we end up with systems which aren't used, don't give any particular value, and certainly don't make sufficient profit to justify themselves. Look at the CT2 telephone system of telepoint for a case study. When this was under development we were always being told how we simply couldn't do without it. In the event, when telepoint started up, users who simply couldn't do without it stayed away from it in droves. Without wishing to rub salt into open wounds, I'd like to point out that even cellular telephone systems are finding it a struggle to survive. Do we really need more complicated systems encompassing greater numbers of users?

We're Getting There...

British Rail has a problem. Well, alright, quite a few problems, really. But train times, crowded accommodation, dirty carriages, bad press and so on aren't at issue here. What is, is the communications network laid along side British Rail's track.

Since BR went into the telecoms business, laying thousands of miles of cable along its nationwide rail tracks and supplying these cables to communications suppliers like Mercury, they have had a problem with thieves. What appears to have been happening is that thieves steal these cables, in an attempt to make money from scrap metal values of copper. Many of British Rail's older cables are of a copper nature, so thieves have had quite a heyday it seems.

Scrap value for copper is around £1000 a tonne — in effect, about £1 a kilogram. Not a bad earner, I guess, if you're that way inclined. There have been unsubstantiated press reports of people getting hundreds of pounds a week in this illicit trade.

Security along the rail lines is obviously difficult to maintain. For a start, it's not possible to put a policeman every 100 yards or so along the track. It's also not feasible, according to British Rail, to put these cables in a secure duct. Instead cables are in a shallow trough, with an easy-to-remove lid, to allow British Rail easy access for repairs and maintenance. Unfortunately, easy access for British Rail means easy access for anyone else, too.

Even though all new cables laid along tracks are of optical fibre, the problem hasn't abated. Thieves still cut them to see what's inside — if it's copper they steal it, if it's optical fibre they leave it. British Rail then has to repair the cut optical fibre cable, or replace the stolen copper cable.

BR's predicament has left Mercury with little option except to change its network. Instead of relying to such an extent on a railbased communications network it will, in future, concentrate on other methods. **Keith Brindley**

ETI NEWS

BT AND IBM UK LEAD THE WAY IN PC VIDEO CONFERENCING

BT Visual and Broadcast Services has demonstrated technology which will enable people to see, speak and work with each other through their PCs. The technology, which uses BT's Integrated Services Digital Network, is designed to operate in conjunction with software from IBM for its PC and PS/2 computers.

Steve Maine, Director of BTVBS, said: "The main benefits to users will be faster decision making, speedier and more efficient use of scarce human skills, cost and time savings from reduced travel and improved corporate communications."

BT' s PC videophone hardware working along with IBM software is said to improve all forms of desk-top interworking, including personal videoconferencing, file transfer and access to remote databases.

The applications will operate using BT's ISDN 2 service. At the moment, potentially 86% of UK businesses have access to ISDN 2 through over 4,000 modern telephone exchanges.

The development is expected to open up a whole range of opportunities to improve corporate management. Other areas affected are: senior management conferences, remote expertise access, project management support, customer support, staff training, teleworking and multimedia information services.

BT envisages the early users will be existing 'information intensive' PC users, working with medium to large sized companies, their customers and suppliers.

The technology uses the recently agreed international set of standards (ratified by the CCITT and known as the H.320 series) which cover H.261 video compression, with synchronised voice and simultaneous information transfer over one or more ISDN channels.

Standards have paved the way for rapid growth in this market. IBM's Networking Strategy Manager Chris Frost said: "Early work completed by IBM's Hursley laboratory and by BT at Martlesham, together with the openness and accessibility of the UK's modern digital public network, makes this an area in which the UK may well lead the world."

A NEW DIMENSION IN TELEVISION FROM SONY

In the continued quest for the ultimate in picture and sound perfection, Sony announce the launch of their HiBlack Trinitron range. This new range is said to offer the ultimate in picture quality, incorporating all the benefits of Black Trinitron, with extra black for supreme contrast, colour, detail and definition. The launch of HiBlack is set to bring a new dimension to TV picture quality.

With the new HiBlack tube, black appears blacker and white appears whiter, resulting in brighter contrast and improved detail. Panel transmission, the ratio of light passing through the screen, is significantly improved. The smaller the panel transmission, the blacker the screen; with 100% panel transmission the panel appears transparent and with 0% transmission, the panel appears black. Where most colour televisions have 50%, the HiBlack range has around 35% panel transmission, making it blacker than any other model on the market. As the 'blackness' of the screen absorbs more of the room light, reduced reflective glare leads to better picture quality and less strain on the eyes.

The 21″ 151cm KVM2 1505 features the new HiBlack tube, increased audio output from 3W to 4.5W RMS, Pan Focus Gun technology, and a 30160190 minute sleep timer which automatically turns the TV to standby. The KVM2 1515 offers all these features, with the additional function of Fastext with 4 page memory. Both models, complete with 21-pin Euro SCART socket for VCR/satellite connection and front AV and Hi8/SVHS soc kets for simple connection to Camcorders, will be available in June at £349.99 and £399.99 (RMAP) respectvely.

Three new models are launched in the X series, the top selling range of NICAM TV's. These models offer the highly advanced 'HiBlack Trinitron' screen with superior NICAM stereo sound. Other features include Fastext with 4-page memory, twin SCART sockets for easy connection to other equipment and front A/V connector and Y/C socket for ease of camcorder connection. Available from April prices will be £549.99, £629.99 and £799.99 (RMAP) respectively.

All models in the new HiBlack range include reversible remote control commanders, with basic and full TV command options and dedicated TV stands.

SUNLIGHT SIMULATION SYSTEM

Sol 2 a cost effective sun simulation cabinet from Uvalight Technology Ltd has recently been upgraded. The new design offers the closest possible duplication of natural sunlight. Other improvements include:- larger test area, better sample access, easy interchange of filters, enhanced light uniformity and longer lamp life.

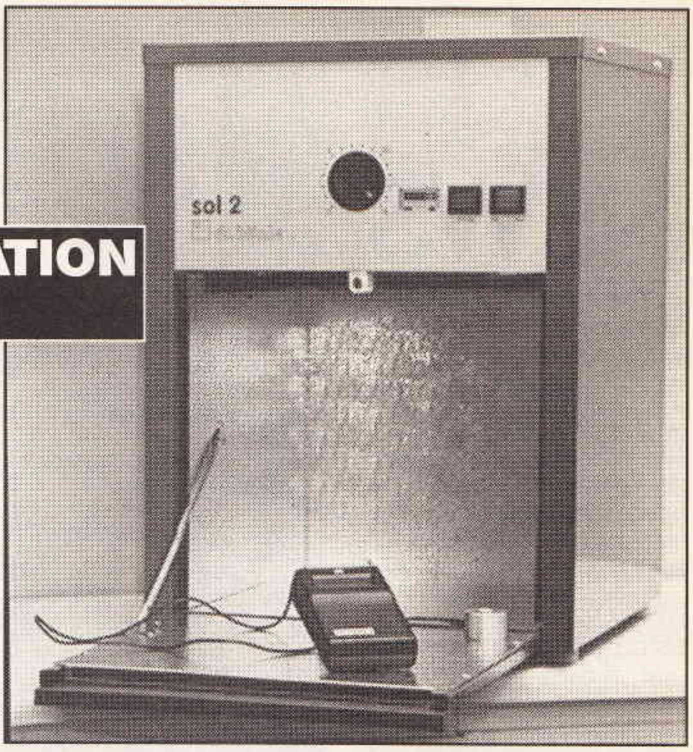
Sol 2 uses a metal halide lamp and filter combination which produce the closest possible duplication of natural sunlight. This ensures that test results provide good correlation to actual climatic conditions.

In addition to the standard sunlight spectrum a further six spectra are available in various wavelength regions by changing lamp/filter combinations. Air mass zero radiation (extra-terrestial) is also available and is used for space application testing.

Approximately 44% of the power input is converted to useful radiation (UV/visible light) and large areas can be uniformly irradiated with intensities between 800-1200 W/m^2. This is consistent with testing standard recommendations and corresponds to an increase over natural radiation intensities by a factor of 6 to 9.

Other modular units are also available for construction of large or small chambers of any size. They can be built into climatic chambers for control of parameters such as temperature, humidity, and rainfall.

For further details contact:- Uvalight Technology Limited: Fax number: 021 643 3879.



LATEST AUDIO-VISUAL TRENDS

The growth of audio/ video integration in the home is reflected by some interesting new research. It is estimated that in 1992 over 40% of all large screen TV's and around 25% of all VCR's will be equipped with Nicam.

Independent statistics reveal that over 15% of consumers have now connected their TV set up to a hifi system. Against this background Sony is launching a sophisticated new AV amplifier, the TAAV670. This model has five separate power amplifiers providing 80 watts per channel for the front, 20 watts per channel for the rear and a centre channel output of 80 watts as well.

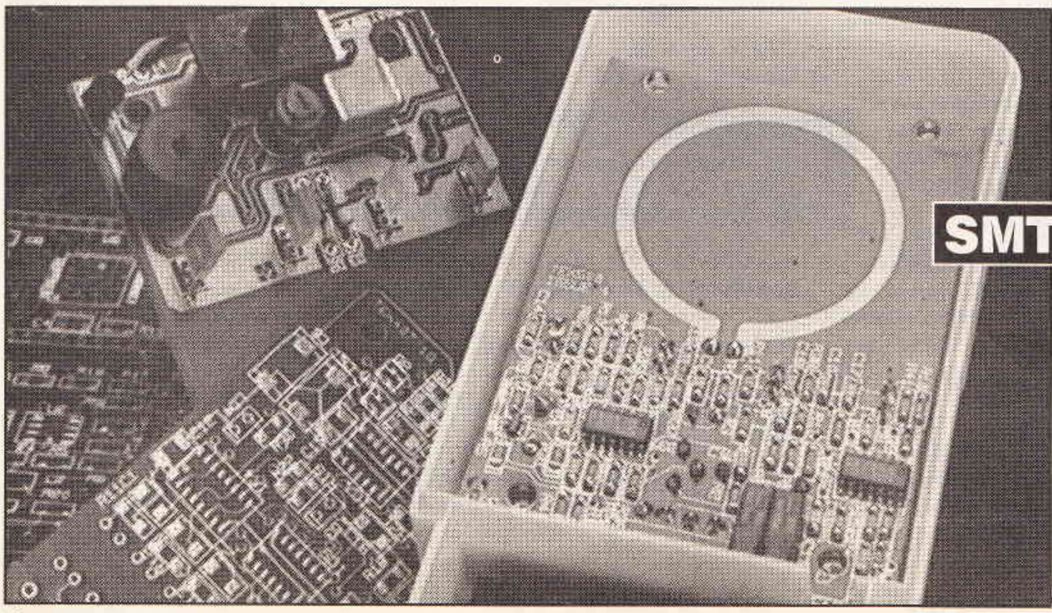
Incorporating advanced Dolby Pro Logic the TAAV670 also provides a Digital Surround Processor by virtue of its DSP function. Overall, five types of surround effect including Dolby, Theatre, Hall, Jazz Club and Stadium can all be enjoyed by simply selecting the surround mode according to the program source.

Within each mode the user can adjust several parameters to maximise the effect in the listening room. For example, it's possible to vary the early reflection time and effect level in the Jazz Club setting by simply rotating the acoustic control. A multi tone control system allows flexible independent adjustment of the front, centre and rear speakers for similar acoustic balance.

The Sony TAAV670 can accommodate up to seven video sources with five separate dedicated audio inputs as well. Sound from various audio programme sources can be added to video programmes using the mix function and a record out selector is also included.

Operational status is indicated by a dot matrix display panel which can be turned off if desired. The user is able to label any input selected with an alphanumeric display of up to eight characters. As well as standard video, five inputs and three outputs for Hi8 or SVHS have been incorporated with handy front mounted sockets behind the control panel flap. A sub woofer may also be connected to the TAAV670 if required.

The TAAV670 is available in August. The price will be £649.99.

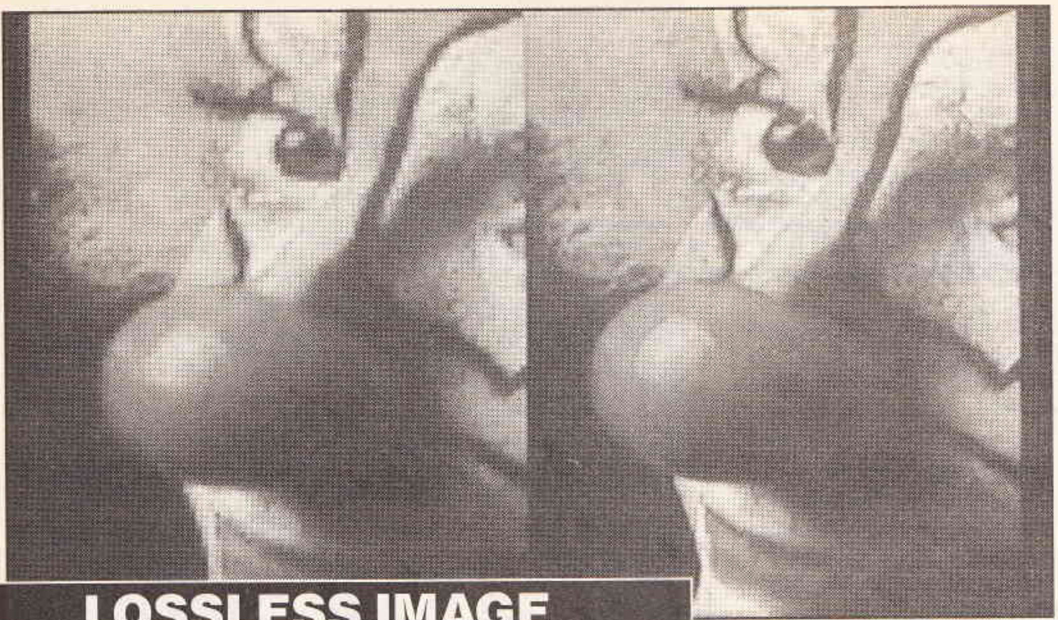


SMT SAVES SPACE

UK Electronics used surface mount technology (SMT) for the basic design in the new TEK instrument range. SMT was chosen to obtain the maximum circuitry on the minimum PCB area with full reliability.

These hand held instruments for electrical safety also inherited other SMT Benefits such as the faster and easier loading of, in general, smaller sized components.

For further information contact Andy Croston at UK Electronics: Tel: 061 6274870.



LOSSLESS IMAGE RESOLUTION

Iterated Systems Ltd has announced details of Fractal Transform Resolution Enhancement, a new lossless technique which allows you to endlessly expand the pixel resolution of digitized images, and to zoom in indefinitely, without blocky pixelation. The result is said to be unparalleled resolution enhancement, superior to any alternative.

Additional detail and image quality is generated by the Fractal Transform, building losslessly on the original image data and maintaining texture and crisp edges. The technique is ideal for all applications that manipulate, edit or manage images, such as desktop publishing and desktop presentations.

Dr Michael Barnsley, Chairman of Iterated Systems and discoverer of the Fractal Transform, commented "This is yet another breakthrough use of our revolutionary Fractal Transform technology, which is already making an extraordinary impact on image compression. Since images are inherently fractal, the Fractal Transform is now revolutionising image technology, just as the silicon chip has revolutionised the electronics industry."

Alice Peters, from Jones & Bartlett Publishers commented "The constant challenge in publishing is to match image resolution to output device, which typically requires 'stretching' images to match output resolutions. This invariably introduces pixelation or other distortion. By contrast, the Fractal Transform Resolution Enhancement technique produces remarkably clear images even at high magnification levels."

Alan McKeon, Managing Director of Iterated Systems' UK subsidiary, commented: "Lossless resolution enhancement is of fundamental importance. The Fractal Transform offers image users the same resolution independent approach to storage, display and printing as Adobe's Postscript has offered to text and comparatively simple graphics."

The enhancement technology is available to end users within Images Incorporated for Windows, the first Fractal Transform image compression software.

A Developer's System for Fractal Transform Resolution Enhancement will be available, containing OBJ and DLL modules for the integration of resolution enhancement into DOS and Windows applications.

Iterated Systems is in negotiation with a number of hardware OEM's to license this breakthrough image resolution enhancement technology.

For further information contact: Jon Blay, Iterated Systems Ltd, Tel: 0734 880261.

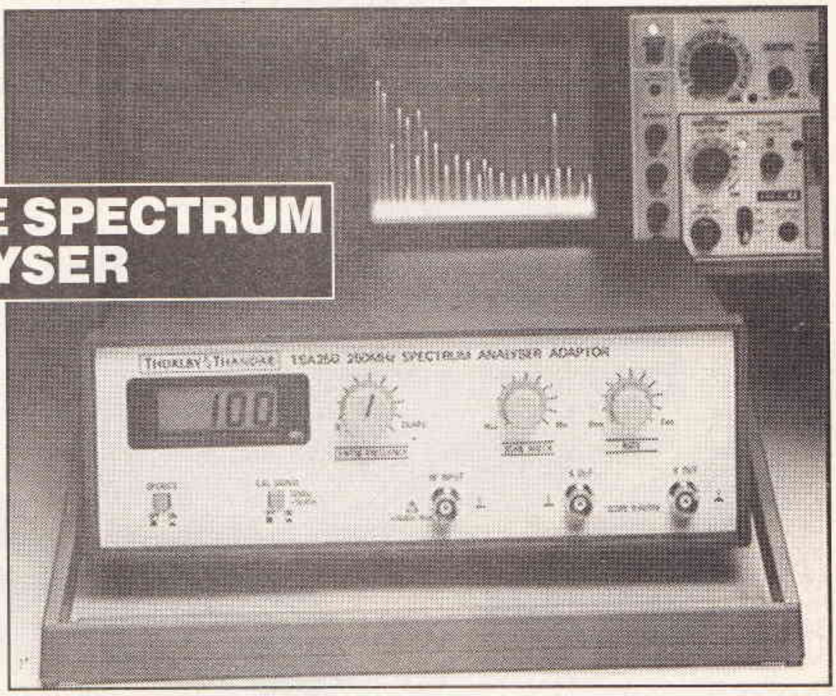
AFFORDABLE SPECTRUM ANALYSER

The new TSA250 Spectrum Analyser Adaptor from Thurlby-Thandar breaks new ground in offering a 250MHz analyser at a low price of £345.00 plus VAT. Thurlby Thandar believe that this will open up many new markets for which spectrum analysers were previously too expensive.

The TSA250 is an adaptor which converts any standard oscilloscope into a Spectrum Analyser and operates over a frequency range of 400kHz to 250MHz and provides a measurement bandwidth of 250kHz. The centre frequency is adjustable over the full range with an integral Liquid Crystal display giving a constant readout of the frequency. Both scan width and rate are also fully adjustable.

The amplitude range is -70 to 0dBm with good accuracy over the whole amplitude and frequency range. A front panel CAL button allows a calibrated -30dBm 50MHz marker signal and its harmonics to be superimposed for precise amplitude and frequency checks.

Connections to an oscilloscope are via two standard BNC cables. The 50 ohms input impedance provides low VSWR for coaxial connections, while high impedance measurements can be made using a standard 10:1 'scope probe.



Applications for the TSA250 include electromagnetic compatibility investigations on electrical equipment, educational demonstrations of spectral phenomena, and the development, production and service of receivers, oscillators and RF amplifiers.

For further information please contact:

Thurlby Thandar Ltd, Fax: 0480 412451

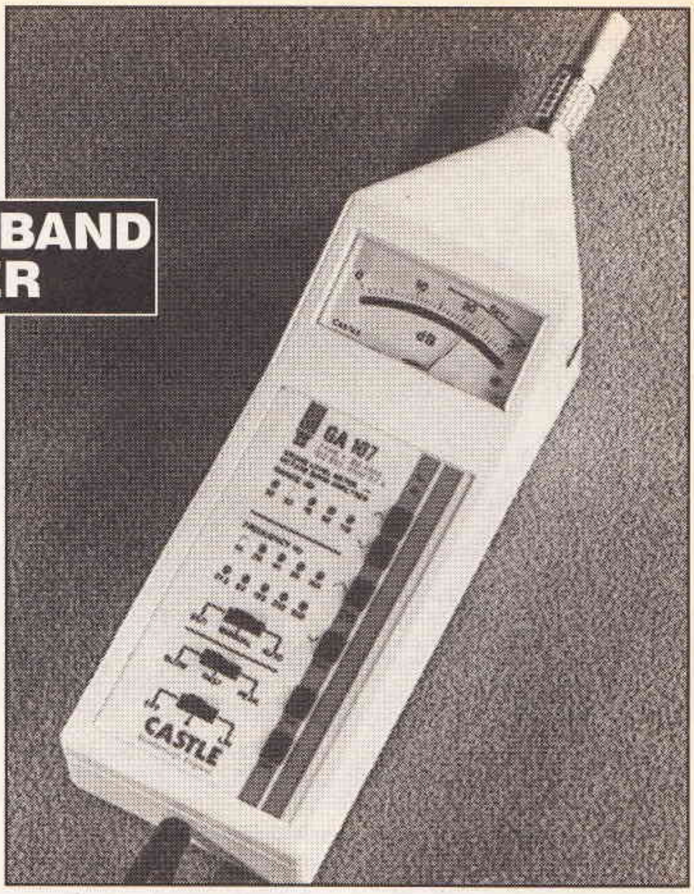
FREQUENCY BAND ANALYSER

Analysis of the character of a noise, enables the user to effectively design noise control, select suitable hearing protection and materials as well as locate a particular noise producing source, the GAl 07 Octave Band Peak Sound Level Meter could be the answer for these requirements.

Ideal uses include public address system work, heating and ventilation systems design, double glazing performance and selection of hearing protection.

For further details contact Sally Mason, Castle Associates:

Tel 0723 584250.



REALTIME CONVERTER PROVIDES PC PICTURES ON TV

A picture appearing on a PC monitor can now be displayed on a TV monitor or recorded by video with the new VGAPAL card from RDA, of Blackwood, Gwent.

VGAPAL is an IBM compatible card that converts, in REAL-TIME, the picture from a VGA graphic card into PAL-CCIR video which can then be recorded or viewed on a standard TV. Being a simple add-on card, the VGA-PAL card does not interfere with graphic functions of the PC, nor with its monitor.

The analogue input conversion uses a high-speed PLL clock synchronized to the graphic sync, and the scanning conversion is performed in real-time, frame by frame, offering a PAL picture fully interlaced and to the highest standard.

The board will plug into any empty slot in the PC and does not require any setting changes to the graphic card. It is connected, using a special plug provided, between the graphic card output socket and the monitor plug.

With this add-on,software houses need no longer send out cut-down versions of their products, they can send out video recordings - with a voice-over.

Other applications include classroom teaching/demonstration situations, where one PC is all that is needed as the converted graphic image may be displayed to the whole class via an overhead video projector.

For conferences,the company accountant can graphically show the company's performance to the other members of the board without the use of more PCs and a complex networking system.

Further enquiries to: Research Development Application: Fax 0495 225540.

COMPACT VIDEO DUBBER ENHANCER

New from Maplin Electronics,is a compact video dubber and enhancer unit that will help to minimize signal degradation when dubbing and/or monitoring video recordings. The cost competitive unit has inputs and outputs for two VCR's and two monitor outputs.

The video source selection is provided by a front panel switch and allows dubbing from VCR A to VCR B whilst monitoring VCR A (switch out) or dubbing from VCR B to VCR A whilst monitoring VCR B (switch in). Rotary controls on the front panel adjust video gain and level of enhancement. The MAPLIN unit may also be used as a video source selector or as a distribution amplifier.

For full details, see page 39 in the 1992 MAPLIN Catalogue.

ETI NEWS stateside

Integrating Roof Antennae

By integrating an antenna into the roof of its minivans, General Motors, working together with 3M Electrical Specialties Division, was able to eliminate the problems of wind noise.

The roof antenna is a conductive, polyester-coated copper film that couples to the vehicle roof rails. This allows it to use other body components —the pillars and various sheet-metal panels - as antenna elements. The thin-sheet antenna has the additional benefit of weighing less than a mast antenna, and since it is inside the vehicle, it creates no aerodynamic drag.

The integral roof antenna is used in the 1992 models of the Chevrolet Lumina APV, Oldsmobile Silhouette, and Pontiac Trans Sport. Engineers were able to incorporate the antenna into the minivans because the vehicles have a plastic roof panel that allows radio signals to pass through to the antenna. Conventional metal roofs block the signals. The roof antenna is said to provide equal FM and better AM reception than a mast antenna.

Electronic guide for travellers

A hand-held electronic guide contains a database with 35,000 entries covering all major interstate highways in the continental U.S. It allows a traveller to plan a trip from one city to another by providing mileage and simple directions for getting there.

While on a trip, users enter the state, highway, direction and nearest mile marker to access information about food, lodging, hospitals, rest stops, and points of interest. The guide will identify the information generically or by brand name, and give direction, exit number, and distance from the current location. Also included is a telephone directory of local highway patrol, weather, and tourist-assistance numbers, as well as toll-free numbers for motels and motor clubs.

The guide, called Interstate Tripmate, from Whistler, Westford, Massachusetts, is updatable and expandable to 100,000 entries by installing plug-in modules.

Advanced Battery Consortium

The Big Three car makers and the U.S. Department of Energy are to collaborate on a research project for the first time. Both car makers and the government will fund the $260 million U.S. Advanced Battery Consortium with the goal of developing a lightweight battery system to make electric vehicles widely available by the year 2000.

The Bush administration considers the project an implementation of its National Energy Strategy as well as an edge against international competition. President Bush stated, "The development of a competitive electronic auto industry will do more to reduce oil imports than rigid fuel-efficiency standards that risk jobs and public safety."

According to Energy Secretary, James Watkins, "DoE and the US- ABC will seek to accelerate the market potential of electric vehicles by collaborating on high-risk, high-cost advanced battery research and development of the most promising advanced battery alternatives by committing their respective resources, including facilities, technology, and people."

Watkins added that the agreement will help improve the environment, advance U.S. technology, and increase industry participation in research and development. He also claimed that the National Energy Strategy will create more than 300,000 new jobs by the end of the decade.

Decreasing grill area of cars

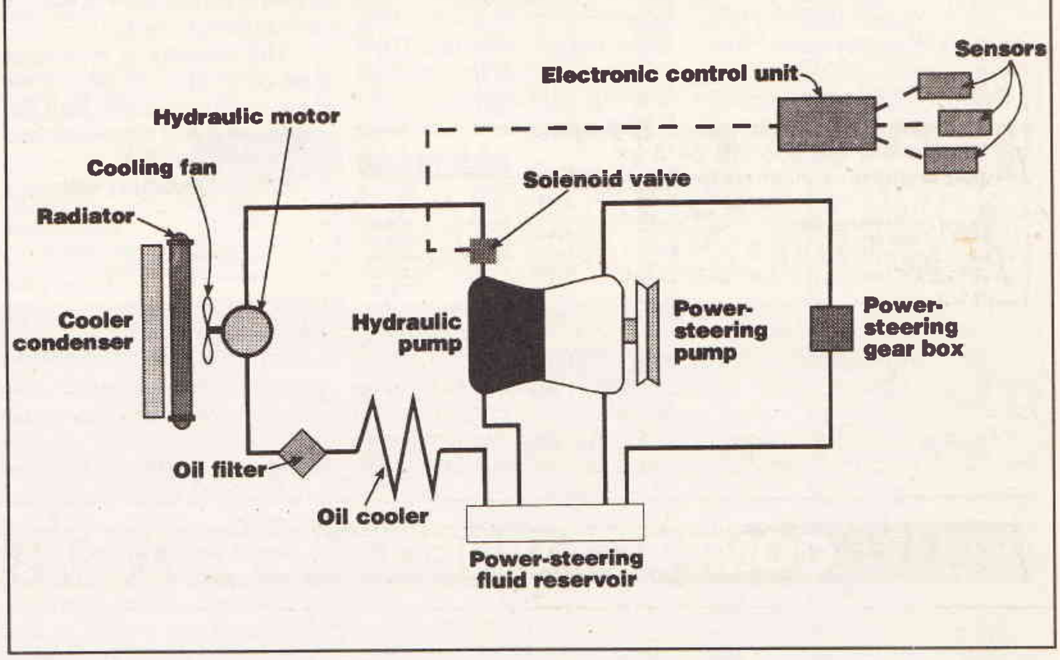
The grill areas on the fronts of cars is decreasing as designs become more aerodynamic. More powerful engine fans are therefore needed to draw air through the smaller grills, but these are usually noisier.

Toyota has developed a fan that runs more quietly than others because it does not run at full speed at all times. The fan matches its speed to engine-cooling requirements, slowing down when the car is idling or otherwise not generating much heat. The electronically controlled hydraulic fan is found in the 1992 Camry 3VZ-FE engine.

The Camry fan is powered by a small hydraulic pump, mounted on the rear of the power-steering pump, that draws fluid from the power-steering reservoir. An electronic-control unit varies fan speed, depending on engine temperature, air-conditioner status, and engine speed. The unit controls the hydraulic pump, which acts in turn to control, a spool valve, the hydraulic fan motor.

Besides being quieter, the Camry fan and accompanying hydraulic system are smaller and lighter than comparable electric fans, which would require an electric motor and larger alternator and battery. The variable load the hydraulic fan exerts on the engine also results in smoother idle and low-speed driveability.

Cooling system arrangement



READ\WRITE

ETI LETTERS

Early Shower Warning

The article by K Garwell intrigued me somewhat, and not wishing to denegrate his efforts, I thought he was a bit 'wide of the mark', in his approach to detecting meteor showers, atmospheric charge etc.

He might be interested in a device invented by me in 1963, patent no. 991646, as no doubt would Mr L Grossan (Tyne and Wear), that not only can detect meteor showers but also give advance warning of a lightning strike to within 10 minutes.

My own studies of atmospheric ionisation have been in intense interest to me, but my main interest in this line of research was more to do with wide spectrum EM sensing.

I am sure both gentlemen will derive great pleasure from their own experiments using an electrometer, though the path they have chosen might not lead to where they expect. One interesting phenomena they might pursue with this HRV instrument, is in the study of dowsing, but I digress....

P Wilkinson,
Lincs

Pre-Amp Praised

I have just finished building the JLH Pre-amp RIAA board and I must agree with Mr Linsley-Hood's comments.

While the noise level and the circuit is more susceptible to mains hum, this is more than compensated by the smoother treble and reduction in surface noise from records.

The pre-amp is very open and clear. Most of all you are now totally involved with the music, your feet tapping up and down to the rhythm.

On the technical side, as I have a low output moving- coil cartridge, I had to replace R9 to 7R. The 2µ2 capitors, as they are in the signal path, I replaced with polypropylene types costing only £1-36 each from Maplin. All resistors are low-noise metal-film also from Maplin along with the low ESR capacitors.

Thanks once again to John Linsley Hood for another excellent circuit which sounds wonderful.

D Lucas,
Glasgow

The Fog Index

Whilst reading some recent article in ETI, I have had to hesitate and re-read part of a long sentence in order to follow the subject unfolding and it has made me wonder whether the authors have ever heard of the 'Fog Index'. I am well aware that article writing is by no means simple and framing the subject in a clear and significant manner is a real art. So may I please introduce the following which I learned from an I.C.E publication:

The Fog Index was devised by Robert Gunning as a means of measuring the comprehensibility of a written work. Test your essay to establish the rating in the following way.

Choose a random number of consecutive sentences, containing in total, approximately 100 words.

Note the number of sentences contained by this group of words and calculate the average number of words per sentence (NWPS).

Using the same words, count the number of words which contain three or more syllables, ignoring proper nouns and words which are three syllables long because of -ed or -es. (TSW).

Add NWPS to TSW and calculate 40% of this total. The answer is the Fog Index (FI) for the piece of writing.

The lower the FI, the more readable is the work. You should aim for a FI of 12 or less. If the FI is greater than 12, either shorten your sentences or use simpler words or both. This should prevent the fog closing in.

It would be interesting to hear the views of both readers and article writers on this aspect.

W Harms,
Bexhill, East Sussex.

It certainly would, Mr Harms. We agree in principle with you. We sit here at the sharp end of it all, trying to make sense of contributors input. In the very small time available (less now than ever before in these lean efficient times) we try to simplify wherever possible. An awful lot escapes owing to the time element. Of all subjects written about, legal documents and technological meanderings must rate highly on the Fog Index or Fog Factor as it has been known. ETI is a magazine for publishing good ideas from creative scientific minds and unfortunately many of those supplying the ideas lack clear expression. It is difficult to make technological jargon interesting. Long convoluted sentences are a common problem and a contributor will often add commas to incorporate all associated facts.

A large proportion of us also have subconscious favorite words or phrases. In speech, these may be 'Um' or 'You know'. On paper we are no different.

Here are a few common repetitious words and phrases found in many contributors notes.

However — Meanwhile — that (most common) — Note that — that is used to — in order that — On the other hand — from the fact that — that which is

Very often they can be left out altogether. With the following list of some common phrases readers might like to suggest simple alternatives.

utilise
taken into consideration
on account of the fact that
leaving much to be desired
in view of the fact that
give rise to
at the present time
act as
in the majority of instances

Some editors prefer to retain the style of the writer. This provides a clue to their character, whereas a highly critical editor would rewrite to his or her style. My preference is to go for the former, removing minor irritations. A guide on lengthy sentences is to read the statements aloud. If you have to pause to take a breath, the sentence could be too long.

PS A quick Fog Index calculation on your letter Mr Harms suggested a figure of 14.4! — Ed

ESR ELECTRONIC COMPONENTS

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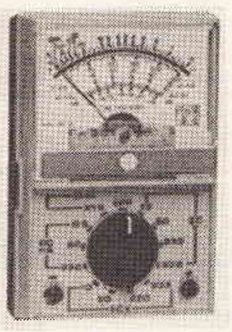
Tyne & Wear NE30 4PQ
Tel: 091 251 4363 Fax: 091 252 2296

TEST AND MEASUREMENT



HC213 ANALOGUE METER
12 ranges, diaode protection, mirrored scale, 2mm leads. Pocket sized, supplied with battery and instructions.
Dim. 90 × 60 × 30mm **£5.96**

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19 ranges (inc 10A dc(, fuse and diode protection, battery test, shock resistant tilted case, mirrored scale, supplied with battery, leads and instructions.
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20 Ranges (inc 10A dc), fuse and diode protection, transistor and diode testing, polarity reverse switch, high impact shock resistant case. Supplied with battery, leads, stand and instructions.
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MX190 DIGITAL METER
19 ranges, 3.5 digit 12mm LCD, signal injector, diode test, fuse protection, auto polarity and zero, supplied with battery, leads and instruction manual.
Dim. 126 × 70 × 24mm **£14.73**

M2315B DIGITAL METER
17 ranges (inc 10A dc), 3.5 digit 12mm LCD, diode test, buzzer, auto polarity and zero, over-range ad low battery indication, supplied with battery, leads and instructions.
Dim. 130 × 72 × 33mm **£23.40**

TL34 DIGITAL METER
33 ranges (inc 20A ac/dc) PTC and fuse protection, 5 capacitance ranges, transistor test, 3.5 digit large 24mm display. Heavy duty case with tilt stand. Supplied with battery, leads and instructions.
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0.47	—	—	£0.05	£0.07
1.0	—	—	£0.05	£0.06
2.2	—	—	£0.05	£0.06
4.7	—	—	£0.05	£0.08
10	£0.05	£0.05	£0.06	£0.08
22	£0.05	£0.05	£0.09	—
47	£0.06	£0.06	£0.11	—
100	£0.06	£0.09	£0.11	—
220	£0.09	£0.12	£0.31	—
470	£0.15	£0.19	£0.57	—
1000	£0.22	£0.29	—	—
2200	£0.37	£0.57	—	—
4700	—	£1.11	—	—

ELECTROLYTIC AXIAL CAPACITORS

uF	16V	25V	63V	100V
0.47	—	—	—	£0.15
1.0	—	—	£0.10	£0.10
2.2	—	—	£0.10	£0.10
4.7	—	£0.09	£0.10	£0.10
10	—	£0.12	£0.12	£0.12
22	—	£0.09	£0.13	£0.17
47	£0.10	£0.11	£0.16	£0.20
100	£0.10	£0.13	£0.21	—
220	£0.13	£0.18	£0.42	—
470	£0.21	£0.20	£0.69	—
1000	£0.33	£0.40	£1.05	—
2200	£0.52	£0.64	—	—
4700	£0.90	—	—	—

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0.25W 5% CF E12 Series	£0.60/100
0.5W 5% CF E12 Series	£0.95/100
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POTS Log or Lin 470R — 1MO 25mm dia 0.25 shaft	£0.40
PRESETS Enclosed Horz or Vert 100R — 1MO 0.15W	£0.15
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5mm Green LED	£0.10
5mm Yellow LED	£0.10
5mm Orange LED	£0.10
3mm Red LED	£0.08
3mm Green LED	£0.12
3mm Yellow LED	£0.13
3mm Orange LED	£0.13
5mm Flashing Red	£0.50
5mm Flashing Green	£0.54
5mm Bi Colour	£0.36
5mm Tri Colour	£0.48
5mm Plastic Bezel	£0.04
5mm Plastic Bezel	£0.05
0.3" 7-Segment Display Red	
common anode	£1.14
common cathode	£1.14

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BTA08-600B	£0.84
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DIAC	£0.20

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SPDT Toggle	£0.54
SPDT CO Toggle	£0.62
DPDT Toggle	£0.68
DPDT CO Toggle	£0.74
DPDT CO Toggle (biased)	£1.20
DPDT CO Toggle (biased 1 way)	£1.20
DPDT mini slide	£0.15
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1 POLE 12 WAY	£0.78
2 POLE 6 WAY	£0.78
3 POLE 4 WAY	£0.78
4 POLE 3 WAY	£0.78
Key Switch SPST	£2.70
Push to make	£0.25
Push to break	£0.24
Latching Push Sqr	£0.58
PCB Tact 6 x 6mm	£0.25

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BNC Crimp Plug	£0.68
BNC Solder Skt	£1.06
BNC Chassis Skt	£0.78
PL259 5.2mm	£0.58
PL259 11mm	£0.58
RND UHF socket	£0.63
SQR UHF socket	£0.40
F Plug RG58	£0.27
F Plug RG6	£0.27
N Plug RG8	£1.84

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W005 1.5A 50V	£0.19
W02 1.5A 200V	£0.20
W10 1.5A 1000V	£0.24
BR32 3.0A 200V	£0.36
BR62 6.0A 200V	£0.64
1004 10.0A 400V	£1.39

D CONNECTORS

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	Plug	Socket
9 Pin	£0.29	£0.30
15 Pin	£0.39	£0.39
15 Pin H.D.	£0.81	£0.90
23 Pin	£0.40	£0.42
25 Pin	£0.48	£0.50
9 Way plastic cover		£0.30
15 Way plastic cover		£0.33
23 Way plastic cover		£0.36
25 Way plastic cover		£0.36

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TL061	£0.35
TL062	£0.42
TL064	£0.46
TL071CP	£0.32
TL072CP	£0.34
TL074CN	£0.48
TL081	£0.29
TL082CP	£0.34
TL084CN	£0.46
TBA120S	£0.77
LM301A	£0.25
CA311E	£0.28
CA324	£0.23
LM348N	£0.31
LF351N	£0.36
LM358N	£0.27
LM377	£2.57
LM380N	£1.12
LM381	£2.70
LM386	£0.48
LM387	£1.60
LM392N	£0.79
LM393N	£0.28
LM394	£3.98
CA555	£0.22
NE531	£1.56
NE5534	£0.66
NE556N	£0.36
NE567N	£0.36
UA733	£0.64
CA741CE	£0.18
CA747CE	£0.39
CA3130E	£0.98
LM748CN	£0.31
TBA810S	£0.68
TBA820M	£0.39
LM1458	£0.26
ULN2004	£0.48
TDA2030	£1.35
CA3046	£0.37
CA3080	£0.72
CA1310	£0.98
CA3140	£0.56
CA3240	£1.22
LM3900	£0.72
LM3914	£2.70
LM3915	£2.70
MC4558	£0.36
NE5532	£0.80
ICL7621	£1.70
ICM7555	£0.43
ICM7556	£0.96
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ZN425E	£4.68
ZN426E	£2.61
ZN427E	£6.82
ZN428E	£6.12
ZN435E	£5.31
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REG'S

78L05	£0.24
78L12	£0.24
78L15	£0.24
79L05	£0.28
79L12	£0.28
79L15	£0.28
7805	£0.28
7812	£0.28
7815	£0.28
7905	£0.38
7912	£0.38
7915	£0.38
LM317T	£0.44
LM723	£0.29
L200CV	£1.24
LM323K	£2.70
LM338K	£5.52

74LS-SERIES

74LS00	£0.14
74LS01	£0.14
74LS02	£0.14
74LS03	£0.14
74LS04	£0.14
74LS05	£0.14
74LS08	£0.14
74LS09	£0.14
74LS10	£0.14
74LS107	£0.23
74LS109	£0.21
74LS11	£0.17
74LS112	£0.21
74LS113	£0.21
74LS114	£0.21
74LS12	£0.14
74LS122	£0.31
74LS123	£0.31
74LS125	£0.21
74LS126	£0.21
74LS13	£0.14
74LS132	£0.21
74LS133	£0.18
74LS136	£0.16
74LS138	£0.24
74LS139	£0.25
74LS14	£0.18
74LS145	£0.56
74LS147	£1.26
74LS148	£0.70
74LS15	£0.14
74LS151	£0.25
74LS153	£0.25
74LS154	£0.70
74LS155	£0.25
74LS156	£0.25
74LS157	£0.25
74LS158	£0.25
74LS160	£0.32
74LS161	£0.32
74LS162	£0.32
74LS163	£0.32
74LS164	£0.26
74LS165	£0.48
74LS179	£0.30
74LS173	£0.24
74LS174	£0.24
74LS175	£0.24
74LS190	£0.25
74LS191	£0.24
74LS192	£0.24
74LS193	£0.24
74LS195	£0.24
74LS196	£0.24
74LS197	£0.24
74LS20	£0.16
74LS21	£0.14
74LS22	£0.14
74LS221	£0.36
74LS240	£0.32
74LS241	£0.32
74LS242	£0.32
74LS243	£0.32
74LS244	£0.32
74LS245	£0.33
74LS247	£0.32
74LS251	£0.24
74LS257	£0.24
74LS258	£0.24
74LS26	£0.14
74LS266	£0.14
74LS27	£0.14
74LS273	£0.32
74LS279	£0.25
74LS30	£0.14
74LS32	£0.14
74LS365	£0.21
74LS367	£0.21
74LS368	£0.21
74LS37	£0.14
74LS373	£0.32
74LS374	£0.32
74LS375	£0.34
74LS377	£0.32
74LS378	£0.62
74LS38	£0.14
74LS390	£0.25
74LS393	£0.24
74LS395	£0.26
74LS399	£0.62
74LS40	£0.14
74LS42	£0.25
74LS47	£0.42
74LS51	£0.14
74LS670	£0.69
74LS73	£0.17
74LS74	£0.19
74LS75	£0.19
74LS76	£0.25
74LS83	£0.31
74LS85	£0.35
74LS86	£0.20
74LS90	£0.23
74LS92	£0.35
74LS93	£0.25

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8 Pin	£0.07
14 Pin	£0.11
16 Pin	£0.15
18 Pin	£0.15
20 Pin	£0.16
24 Pin	£0.19
28 Pin	£0.22
40 Pin	£0.25

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Zener Diodes 2V7 to 33v

BZY88400Mw	£0.08
BZY851.3W	£0.14
IN4001	£0.06
IN4002	£0.07
IN4003	£0.07
IN4004	£0.07
IN4005	£0.07
IN4006	£0.08
IN4007	£0.08
IN5400	£0.09
IN5401	£0.09
IN5402	£0.09
IN5404	£0.11
IN5406	£0.11
IN5407	£0.14
IN5408	£0.15
IN914	£0.06
IN916	£0.06
IN4148	£0.05
BY133	£0.13
OA47	£0.28
OA90	£0.07
OA91	£0.10
OA202	£0.14
BA157	£0.10
BA158	£0.10
BA159	£0.10
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4000	£0.17
4001	£0.17
4002	£0.17
4006	£0.32
4007	£0.17
4008	£0.31
4010	£0.23
4011	£0.16
4012	£0.16
4013	£0.17
4014	£0.30
4015	£0.31
4016	£0.18
4017	£0.25
4018	£0.27
4019	£0.19
4020	£0.31
4021	£0.31
4022	£0.32
4023	£0.16
4024	£0.21
4025	£0.15
4026	£0.40
4027	£0.18
4028	£0.22
4029	£0.27
4030	£0.17
4031	£0.70
4033	£0.56
4034	£1.24
4035	£0.31
4040	£0.29
4041	£0.31
4042	£0.22
4043	£0.28
4044	£0.31
4046	£0.31
4047	£0.25
4048	£0.31
4049	£0.20
4050	£0.20
4051	£0.25
4052	£0.25
4053	£0.25
4054	£0.56
4055	£0.30
4060	£0.31
4063	£0.29
4066	£0.18
4067	£1.91
4068	£0.16
4069	£0.20
4070	£0.17
4071	£0.20
4072	£0.17
4073	£0.17
4075	£0.17
4076	£0.30
4077	£0.17
4081	£0.14
4082	£0.17
4085	£0.28
4086	£0.26
4089	£0.55
4093	£0.15
4094	£0.31
4095	£0.56
4097	£1.20
4098	£0.31
4099	£0.38
4502	£0.38
4503	£0.31
4508	£0.90
4510	£0.26
4511	£0.29
4512	£0.31
4514	£0.73
4515	£0.78
4516	£0.31
4518	£0.27
4520	£0.26
4521	£0.62
4526	£0.40
4527	£0.39
4528	£0.40
4529	£0.44
4532	£0.31
4534	£2.24
4536	£1.00
4538	£0.37
4541	£0.31
4543	£0.46
4555	£0.34
4556	£0.34
4560	£1.18
4566	£1.96
4572	£0.25
4584	£0.24
4585	£0.32
4724	£0.70
40106	£0.24
40109	£0.50
40163	£0.46
40174	£0.34
40175	£0.36
40193	£0.60

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2N1613	£0.31
2N1711	£0.26
2N1893	£0.29
2N2218A	£0.28
2N2219A	£0.25
2N2222A	£0.16
2N2646	£0.80
2N2904A	£0.25
2N2905A	£0.23
2N2907	£0.20
2N2926	£0.16
2N3053	£0.27
2N3054	£0.90
2N3055	£0.62
2N3440	£0.50
2N3702	£0.09
2N3703	£0.10
2N3704	£0.10
2N3705	£0.10
2N3706	£0.10
2N3771	£1.44
2N3772	£1.51
2N3773	£1.79
2N3819	£0.40
2N3820	£0.58
2N3904	£0.10
2N3905	£0.10
2N3906	£0.10
2N4036	£0.31
2N5296	£0.57
2N5321	£0.57
2N6107	£0.60
AC126	£0.30
AC127	£0.30
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BC107	£0.14
BC107B	£0.15
BC108	£0.12
BC108A	£0.14
BC109	£0.14
BC109C	£0.15

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PO102AA	£0.30
TIC106D	£0.40
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TIC126D	£0.77

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Ceramic Plate 100V and 63V 1.0pf to 12nf
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3n3-4n7 £0.12 10nf and 12np £0.12
Polystyrene 160V 47pf to 10nf
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BBC Model B APM Board

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£100 CASH FOR THE MOST NOVEL DEMONSTRATABLE APPLICATION!

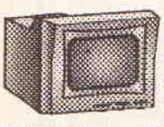
BBC Model B type computer on a board. A major purchase allows us to offer you the **PROFESSIONAL** version of the BBC computer at a parts only price. Used as a front end graphics system on large networked systems the architecture of the BBC board has so many similarities to the regular BBC model B that we are sure that with a bit of experimentation and ingenuity many useful applications will be found for this board!! It is supplied complete with a connector panel which brings all the I/O to 'D' and BNC type connectors - all you have to do is provide +5 and ± 12 v DC. The APM consists of a single PCB with most major ic's socketed. The ic's are too numerous to list but include a 6502, RAM and an SAA5050 teletext chip. Three 27128 EPROMS contain the custom operating system on which we have no data. On application of DC power the system boots and provides diagnostic information on the video output. On board DIP switches and jumpers select the ECONET address and enable the four extra EPROM sockets for user software. Appx. dims: main board 13" x 10". I/O board 14" x 3". Supplied tested with circuit diagram, data and competition entry form.

Only £29.95 or 2 for £53 (B)

MONITORS

MONOCHROME MONITORS

THIS MONTH'S SPECIAL!



There has never been a deal like this one! **Brand spanking new & boxed** monitors from NEC, normally selling at about £140! These are over-engineered for ultra reliability. 9" green screen composite input with etched non-glare screen plus switchable high/low impedance input and output for daisy-chaining. 3 front controls and 6 at rear. Standard BNC sockets. Beautiful high contrast screen and attractive case with carrying ledge. Perfect as a main or backup monitor and for quantity users! **£39.95 each** (D) **or 5 for £185**(G)

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COLOUR MONITORS

Decca 16" 80 budget range colour monitor. Features a PIL tube, beautiful teak style case and guaranteed 80 column resolution, features usually seen only on colour monitors costing 3 times our price! Ready to connect to most computers or video outputs. 75Ω composite input with integral audio amp & speaker. Fully tested surplus, sold in little or hardly used condition with 90 day full RTB guarantee. Ideal for use with video recorder or our Telebox ST, and other audio visual uses. £99(E) 3/£275(G)

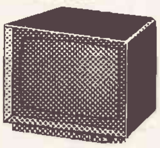
20", 22" and 26" AV SPECIALS

Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & sound inputs. Attractive teak style case. Perfect for Schools,Shops,Disco, Clubs. In EXCELLENT little used condition with full 90 day guarantee.

20"....£135 22"....£155 26"....£185 (F)

CALL FOR PRICING ON NTSC VERSIONS!

HI-DEFINITION COLOUR MONITORS



Brand new 12" mutlinput high definition colour monitors by Microvitek. Nice tight 0.31" dot pitch for superb clarity and modern metal black box styling. Operates from any 15.625 khz sync RGB video source, with either individual H & V syncs such as CGA IBM PC's or RGB analog with composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 14" x 12" square. Free data sheet including connection information. Will also function as quality TV with our RGB Telebox.

Only £145 (E)

Brand new Centronic 14" monitor for IBM PC and compatibles at a lower than ever price! Completely CGA equivalent. Hi-res Mitsubishi 0.42 dot pitch giving 669 x 507 pixels. Big 28 Mhz bandwidth. A super monitor in attractive style moulded case.Full 90 day guarantee. **Only £129** (E)

NEC CGA IBM-PC compatible. High quality ex-equipment fully tested with a 90 day guarantee. In an attractive two tone ribbed grey plastic case measuring 15"L x 13"W x 12"H. A terrific purchase enables us to pass these on at only.... **£79** (E)

V22 1200 BAUD MODEMS

Master Systems 2/12 microprocessor controlled V22 full duplex 1200 baud modem. Fully **BT approved** unit, provides standard V22 high speed data comm, which at 120 cps, can save your phone bill and connect time by a staggering 75%! Ultra slim 45 mm high. Full featured with LED status indicators and remote error diagnostics. Sync or Async use; speech or data switching; built in 240v mains supply and 2 wire connection to BT. Units are in used but good condition. Fully tested prior despatch, with data and a full 90 day guarantee. What more can you ask for - and at this price!! **ONLY £69** (D)

IBM KEYBOARD DEALS

A replacement or backup keyboard, switchable for IBM PC, PC-XT or PC-AT. LED's for Caps,Scroll & Num Locks. Standard 84 keyboard layout. Made by NCR for the English & US markets. Absolutely standard. Brand new & boxed with manual and key template for user slogans on the function keys. Attractive beige,grey and cream finish, with the usual retractable legs underneath. A generous length of curly cord, terminating in the standard 5 pin DIN plug. A beautiful clean piece of manufacturers surplus. What a deal! **£39** (B) **5/£175** (D)

Brand new and boxed 84 key PC/XT type keyboards in standard IBM grey with very attractive mottled finish and "clicky" solid feel keys. 10 function keys on side. English layout and £ sign. Green LEDs for Caps, Scroll & Num locks. **£29.95** (B) **5/£135** (D)

CALL FOR DISCOUNTS ON HIGHER QUANTITIES!

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NEW 5¼ inch from £29.95!

Massive purchases of standard 5¼" drives enables us to present prime product at industry beating low prices! All units (unless stated) are removed from often brand new equipment and are fully tested,aligned and shipped to you with a 90 day guarantee and operate from +5 & +12vdc, are of standard size and accept the standard 34 way connector.

TANDON TM100-2A IBM compatible DS	£39.95(C)
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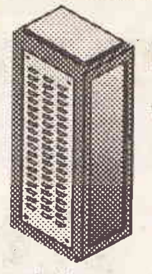

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Improved LED Bicycle Rear Lamp

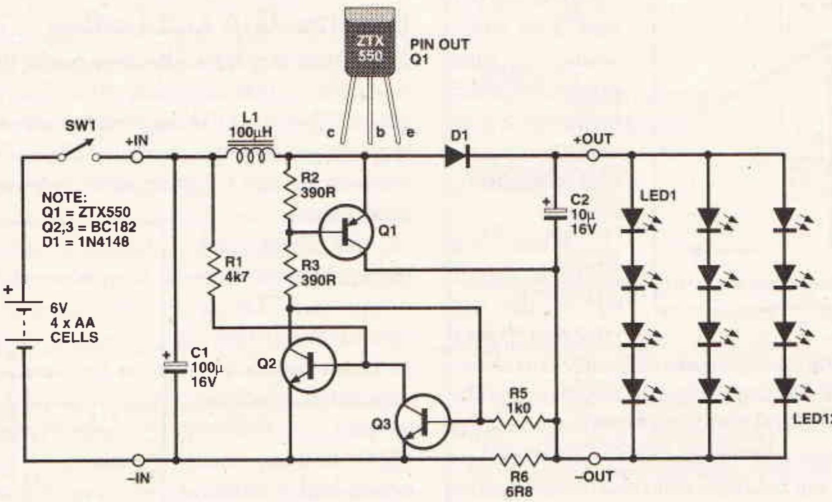


Fig.1 LED bicycle rear lamp circuit diagram

Andrew Armstrong provides a more efficient backlight for a bike.

The simple LED bicycle lamp solved the problem it was intended to solve — that of having a lamp small enough to carry around all day to prevent it being stolen or vandalised, but its PP3 battery ran down too quickly for long-distance use. A rechargeable battery would have solved the problem, but rechargeables run out suddenly. The light is bright one minute and completely absent the next. Primary batteries, on the other hand, degrade gradually enough to give warning that a replacement is necessary, and do not leave you half way up the hill with large vehicles whizzing past just as your light fails.

The simple bikelight was built in one evening — using a full-specification red lens cannibalised from a damaged lamp — to solve an immediate problem, which it is still working well two years later. A more sophisticated solution is possible, however; one area of improvement is a cheaper and more efficient type of battery. An alkaline PP3 costs about £2.80p, and a set of four AA cells costs around £3, but even if the power were used no more efficiently in the new design, the batteries would last over three times as long as the single PP3, because a single AA cell has 80% of the energy content of the PP3.

At full price (and in many shops you would pay less), a PP3 offers you two watt-hours per pound sterling, while an AA cells offers you 6.23 watt-hours per pound. This design also uses the batteries more efficiently than the simple one, so that a set of batteries may last four times as long.

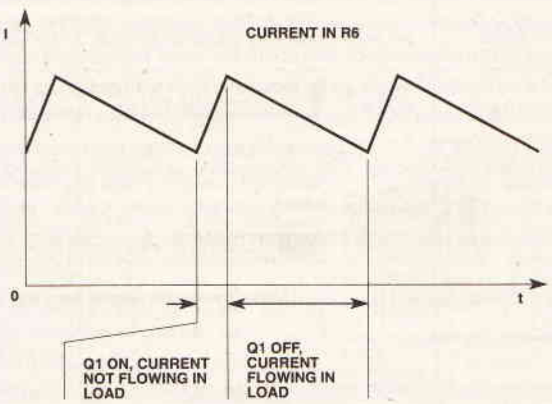


Fig.2 Graph showing variation in current in R6

Constant Current

Light-emitting diodes must be driven from a constant current, rather than a constant voltage source. The easy way to provide this would be to supply a higher voltage than the LED via a resistor to limit the current. For example, three LEDs in series, totally almost 6V, would be driven from a 9V battery via a 100 ohm resistor giving an LED current of approximately 30mA. The drawback with this approach is that one-third of the power is wasted in warming up the resistor; this offends my sense of economy.

The design shown here in Figure 1 provides a constant current by means of a switched mode flyback regulator, and the only power wasted is in incidental circuit losses.

The input voltage to the circuit is 6V, while the output voltage is set by the drop of four LEDs in series, approximately 7.5V. Three parallel chains of LEDs are used here, and the currents in each one will be similar as long as the same type of LED is used throughout. If a serious imbalance is present, then constructors may need to add series resistors of 22R in each line to equalise the current. This would waste some power, but much less than is normally wasted in a current-limiting resistor.

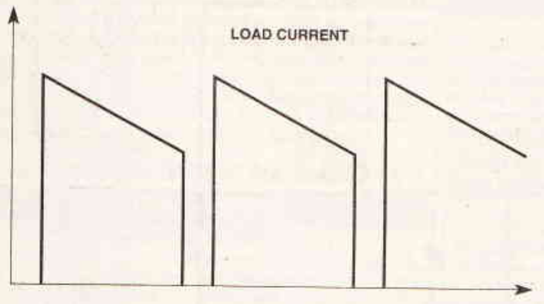


Fig.3 Graph of Load current

When the circuit is switched on, the current in L1 (and therefore in R6) is zero, so Q3 is switched off. This allows Q2 to be switched on by the current flowing through R1. This in turn switches on Q1, causing the current in L1 to rise. While Q1 is switched on, the current does not pass through the LEDs, but is simply returned to the negative battery terminal via R6.

When the current rises far enough so that the voltage drop across R6 is sufficient to start switching on Q3, Q2 starts to switch off, which turns Q3 on harder via the positive feedback resistor R4. This switches off Q1, and the current flowing in the inductor now passes through D1 and through the LEDs. Because the voltage across the LEDs is greater than the input voltage from the batteries, the current in L1 declines. When it has declined far enough to allow Q3 to switch off, Q2 switches on, which turns on Q1, and the whole process starts again. This gives rise to the graph of current in R6 as shown in Figure 2.

The action of the circuit is to approximately regulate the average current in R6. It might at first appear that this also regulates the current in the load, but that is not entirely true. Current flows in the load only during the declining part of the current waveform, as shown in Figure 3, so that an increased differential between input and output voltages will result in a different time-relationship between the two parts of the waveform, and therefore a different average LED current. The LED current is regulated to some extent, because it approaches a limiting value as the on-time of Q1 shortens.

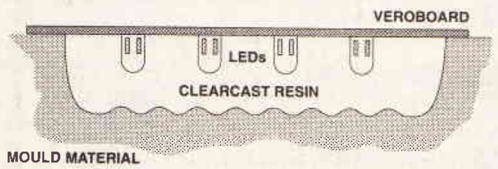


Fig.4 Cross section of LED display and casing

The current in the LEDs does not pulsate as shown in Figure 3, because of the presence of C2. Strictly speaking, the waveform in Figure 3 corresponds with the current in D1, and the LED current is averaged by C2.

As the batteries run down, and the input voltage decreases, the on-time of Q1 increases. Initially, this has little effect on the average LED current, because the on-time of Q1 is still a small proportion of the total cycle time. As the voltage decreases further, the effects upon the LED current of the decrease become more pronounced, though the LEDs still give out some light, until the circuit ceases to oscillate properly at around 2.5V. The practical limit for useful light output is just over 3V. When a nominally 6V battery pack is almost down to 3V, most of the energy has been extracted from the batteries, and they can be thrown away with a clear conscience.

Construction And Testing

This circuit may be constructed on the PCB designed for it, or the constructor may do a Veroboard layout if desired. Layout of this circuit is not critical, though if large loops of wiring exist in the main current loop between C1 and C2, then some radio interference may be radiated.

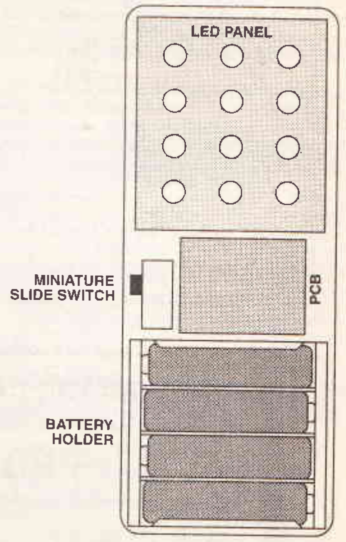


Fig.5 Overall positioning of parts

As with the simple bicycle lamp design, the LEDS are spaced evenly on a panel of Veroboard connected in series-parallel as shown. This design uses twelve LEDs, rather than the nine used in the simple one, so it is capable of giving more light output with a better dispersion. Once again, if a lens from an otherwise defunct bicycle lamp is available, then the LED panel should be fitted behind this. Because the contacts in a bicycle lamp tend to corrode, a lens may be available from one which has corroded past reasonable repair.

Should no suitable lens be available, a good alternative is to encapsulate the LED panel (after it has been thoroughly tested, of course) in clearcast resin. To do this, it will be necessary to make a mould along the lines shown in Figure 4. The base of the mould needs to be dimpled in order to diffuse the light adequately. It is of no use if the rear lamp can be seen properly from only one angle. Some drinking glasses have suitable surfaces which could be used to stamp the mould material.

When the PCB has been assembled, it should be tested by connecting the LED panel to the output of the PCB, and connecting a supply of approximately 3V to its input. The LEDs should light. If they do, the input voltage should be increased to 6V, where the LEDs should become considerably brighter. If all is still well, then the circuit is working properly.

If the LEDs did not light, first of all check the polarity of both the 3V power supply and of the LED panel, and then check through the circuit, one component at a time, to find the problem. One fairly likely snag is that the connections of Q1 appear in the reverse direction from those of a normal TO92 transistor, so this is the first component to check if it doesn't work.

It is advisable to carry out these tests before encapsulating the LED panel.

When the PCB is working correctly, all the connections to it should be made and then it should be covered with several coats of PCB lacquer or varnish to protect it from the effects of the weather.

Final Assembly

When the separate parts are protected from the elements, the board, LED panel, switch and battery should be wired together, as shown in the circuit diagram. The batteries must be protected from the weather, or else the contacts will corrode and the light will fail. Constructors may wish to devise their own method of doing this, but one suitable means would be to use the 'AA battery box', which accepts four AA cells in a square configuration. This will fit inside a hinged, polypropylene battery holder, available from Maplin. These two items are the ones specified in the parts list.

Depending on preference, the PCB may be thoroughly varnished and then left open, it may be enclosed in a small plastic case, or it may be encapsulated in clear-cast resin or silicone rubber.

To complete the project, the LED panel, the PCB, the switch and the battery holder should be mounted on a strip of Paxolin or blank PCB, approximately as shown in Figure 5. These items may be mounted using double-sided adhesive tape. This is very secure if the surfaces to be stuck are scrupulously clean. Any trace of grease, even from normal fingerprints, can undermine the adhesion.

The project is now ready for use.

PARTS LIST

RESISTORS (all 0.25W 5%)

R1	4k7
R2,3	390R
R4	100k
R5	1k
R6	6R8

CAPACITORS

C1	100µ, 16V Electrolytic
C2	10µ, 16V Electrolytic

SEMICONDUCTORS

Q1	ZTX550
Q2,3	BC182
D1	1N4148

LED1-12 High efficiency red leds eg Maplin type UK19V

MISCELLANEOUS

L1	100µH, 8RBS choke (Cirkit order code 262LYF-0092K)
SW1	Slide Switch (Cirkit order code 53-76320)
4AA	Battery box (Maplin order code HF29G)

Battery holder (Maplin order code HY32K)

PCB, wire, solder, strip of paxolin etc, 4 x AA cells.

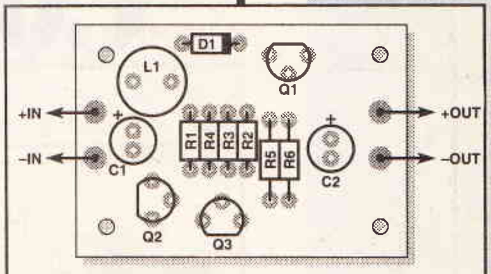


Fig.6 Component overlay

New Concepts in Optical Connectivity

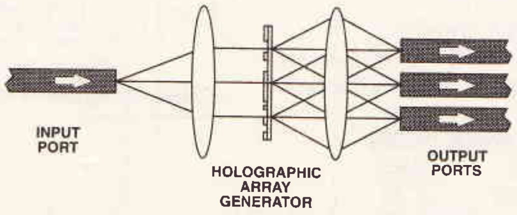


Fig.1 The output from the input fibre is replicated by the holographic array generator with the output Gaussian beams being coupled to an output set of fibre ports.

by Douglas Clarkson

While light may be increasingly used as the method of choice of transmitting digital information, electrical switch mechanisms still dominate present methods of switching technology. But as interconnection densities increase and also the associated problems of connectivity, speed and size of systems dominate, then optical switch technology will become increasingly attractive and indeed essential in some areas.

Optical technology has been investigated extensively in the area of 'optical logic' yet no significant breakthrough has been forthcoming. The bulk of this work relates to allowing light interaction processes to undertake logic switch and memory processes. It is the 'connectivity' aspect of photonics that research is at last bearing fruit. A broad range of approaches are at present being investigated to produce the working technology for such systems.

In particular in communications switching applications, elements of technology are beginning to emerge which will allow the goal of such optical switching to be realised.

It is important to appreciate the fundamental difference between 'electron' based information switching and 'optical' information switching. In the use of electrons as message carriers, currents have to be carried along insulated channels or wires. Essentially electrons are 'fermions' or strongly interacting particles. There are very real limits as to the packing density of independent current carrying channels brought about by their strong mutual interactions.

By contrast, beams of light made up of photons called boson particles, can be made to pass through each other with no crosstalk. Also, within an array of points of light, individual channels can be placed very much closer together —allowing vastly increased channel densities as will be described later. It will be many decades before the fundamental limitations of photonic connectivity are reached. The connection densities which such systems will then support will be staggering.

There are at present a number of initiatives world wide to develop the full potential of photonic connectivity. If optical switching technology is used for data channel switching in a complex 'many-to-many' arrangement, then a set of optical technology 'building blocks' is required. This article briefly examines a few of these ideas, some of which have been investigated in the Department of Physics at King's College, London.

The principles used in the technology are not themselves new. It is, however, the availability of modern fabrication technology which allows age old optical laws to be harnessed for such applications.

Such photonic 'building blocks' include :

a) —lens devices to create a Gaussian beam profile from a fibre port to an input of array generators or for array generator output

b) —array generators to replicate a given input pattern (Dammann grating or Hologram types)

c) —spatial light modulators (SLMs) to dynamically alter channel switching links

d) —'smart pixel' elements of SLMs to interact with channel data in an 'intelligent' way

Fig.2 A 64×64 pixel binary phase hologram which diffracts light into 4×4 odd orders.

While previously some of these optical components were only produced within R&D laboratorys, a growing number of items are now commercially available. This has significantly increased the pace of developments generally. There is an obvious parallel between the expansion of micro-electronics and the availability of chip technology.

One important building block is shown in Figure 1 where a 'one-to-many' fan out can be achieved using an

OPTICS

input fibre. A first lens element, a holographic array generator and a second lens element are coupled to a set of output fibre ports. The initial input beam is replicated in the form of an N×N array. Such array generators can be produced either using a so called binary phase diffraction grating (Dammann gratings) or a binary phase hologram. Dammann gratings were initially developed for applications relating to photolithographic reproduction within the semiconductor manufacturing industry. It is essential that light is incident on the surface of these elements in a Gaussian distribution. Arrays as high as 128x128 have been demonstrated, using these techniques —ie. from one Gaussian input an array of 128 by 128 output points has been established.

Problems in making these has produced a variability of output from element to element and very often the central 'straight through' has a higher output value than the other elements. Figure 2 shows a 64×64 pixel binary phase hologram which diffracts light into 4×4 odd orders. One application of this technology relates to the synchronisation of clock signals within electronic circuits. Improved synchronisation can be achieved by distributing a master clock signal as a one-to-many optical signal through optical fibres or through free space and where electronic clock signals are regenerated at each end point. This replication can take place by means of discrete fibre optic links and also free space generated arrays.

This idea has been more recently extended to the idea of the high density optical bus where many thousands of connections run between modules functioning using conventional electronic circuitry. The optical links are used primarily on account of their powers of connectivity.

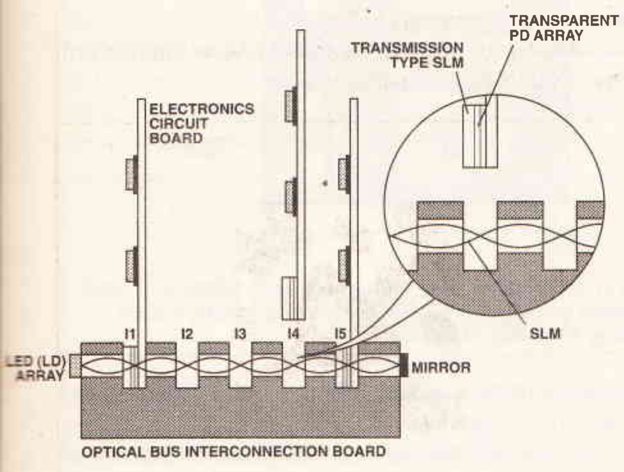


Fig.3 Proposed model of optical bus connectivity. A parallel light wave bus communicates with electronic cards.

This technology is being proposed as a means of implementing parallel optical bus designs for VLSI interconnection in a similar manner to electronic back planes. Such a facility would allow parallel connections of many thousands of data lines between the bus and electronic based circuit boards with photodiode arrays and transmission type spatial light modulators. In the analysis of a 'modest' back plane with 100×100 channels, with a lens diameter of 4mm, optical information theory still indicates that the value of space occupied by each channel could be reduced by a factor of around 1000. Where these very high connection densities are required, then optical mechanisms appear the only way of implementing them.

One arrangement of such an optical bus is shown in Figure 3 where data can be communicated from the bus into circuit cards and circuit cards can modulate light levels within the bus itself. The very great scope to reduce the interconnection volume of each optical channel has generally been restricted due, for example to problems of size of lens elements manipulating individual beams either as input or outputs to Fourier plane array generators. The recent availability of GRIN (gradient refractive index) lenses, is a step forward in achieving relevant miniaturisation of such components.

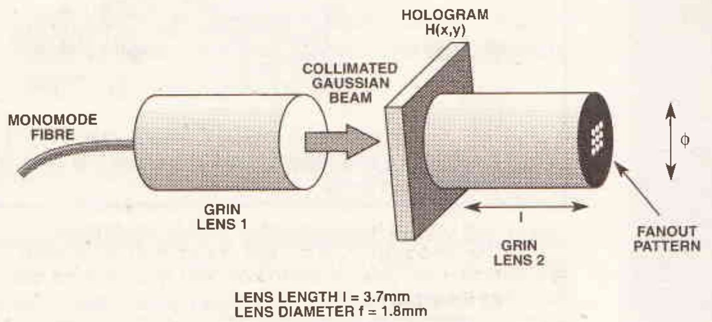


Fig.4 Integration of GRIN lens with monomode fibres and hologram structures

The refractive index of these minute cylindrical lenses decreases with radius according to a specific mathematical formula.

$$n = n_o\left(1 - \frac{A\,r^2}{2}\right)$$

where n is the refractive index, r is the distance from the centre of the lens and A is a constant of the lens material. This gives the lens the property of a Fourier transform lens, enabling a monomode fibre output to be transformed by the GRIN lens to create a collimated Gaussian beam for fan out by a hologram device or Dammann grating. Acting in reverse, a second GRIN lens can create a fan out of similar Gaussian beams for coupling to output fibres.

Figure 4 shows integration of GRIN lens with monomode fibres and hologram structures.

In work undertaken at King's College, a lens of diameter 1.8mm and length 3.7mm was used to construct a 5×5 array of fanout points. These lenses therefore provide the degree of miniaturisation required for compact switching circuitry. For a lens of this size, it is considered possible to accommodate a maximum fan out array of around 25×25. Applications for such technology are anticipated in a general parallel channel facility, where an input image of M×M array is replicated by a M×M Hologram unit and associated GRIN lenses.

Researchers expect this will be a natural way of parallel processing of image data, where an initial image array can be simultaneously replicated as required. This technology appears to be moving towards modular

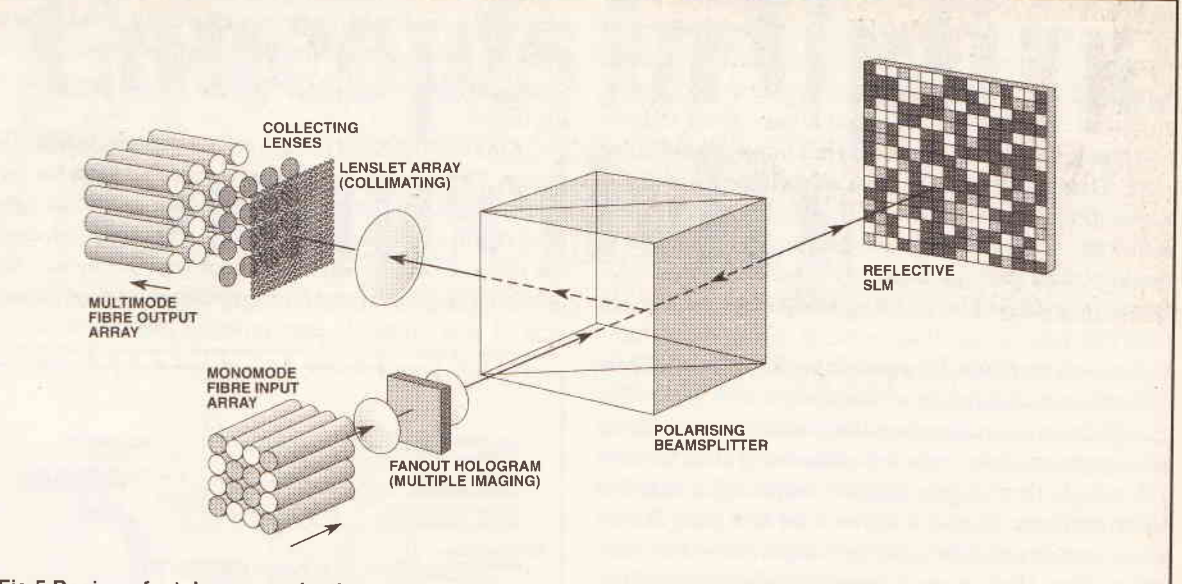


Fig.5 Design of a telecommunications cross bar switch where elements of an N×N input array are switched to an NxN output array.

components with specific array size and channel separations.

The multiple image of the input array could in turn be altered by a spatial light modulator (SLM) or in turn be interfaced directly to a photodiode detector array.

In relation to specific applications in telecommunications switching, Figure 5 shows how a cross bar switch can be set up using optical technology. The initial monomode fibre input array is replicated by a fanout hologram and passes through a polarising beam splitter onto a reflective SLM. This rotates the polarisation of beamlets which are to be transmitted to the output channels. An array of collimating lenses collects light onto the output set of fibres. A complex algorithm implemented by the reflective SLM effectively maps input channels to output channels.

Since fanout holograms have reported densities in the region of 128x128, the limitation of the switching technology relates to aspects of size of individual SLM elements and their associated level of cross talk. Using current SLM devices fabricated from ferroelectric crystal, the maximum number of channels which can be interconnected is in the region of 1000. Data rates in excess of 1 Gbit per channel are expected. Comparable switching mechanisms are being developed by researchers at AT&T using self-electro optic effect devices (S-SEEDs).

In the development of the new parallel electro optic architectures, the so called 'smart pixel' SLM element offers greater flexibility of system design. Such a device is shown in Figure 6. The 'smart pixel' can be considered to have:

— an electronic input from local/external circuits
— an electronic output based on received optical data and local logic control unit
— an optical modulation pad to alter reflected/transmitted light
— an optical detection pad

The 'smart pixel' can therefore be considered to process data 'more intelligently' than a dumb SLM element. In connective optical structures, an array of 'smart pixels' could be used as the plane of termination for a complex sequence of parallel optical data processing units. The design of such devices allows parallel image processing where information about 'local' conditions can be used

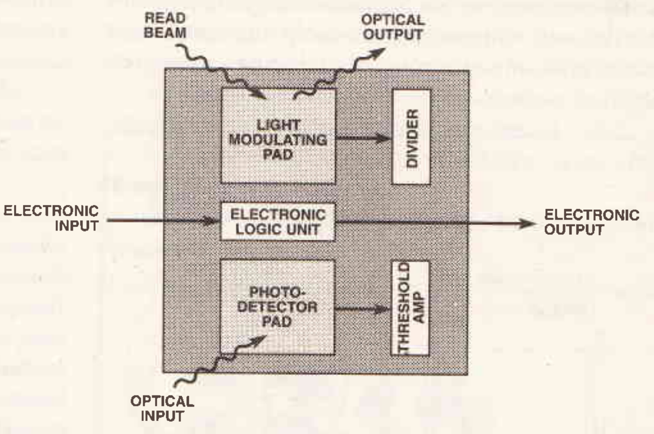


Fig.6 Design of 'smart pixel' SLM unit, where both global and local processing can influence pixel processing function, thus increasing flexibility of device.

to determine how image data is processed. This increases speeds of processing.

While the 1980's saw the emergence of optical computing in terms of innovative optical logic structures, the 1990's are witnessing the emergence of practical development of optical interconnect technologies. The work being undertaken in the UK at centres such as King's College in demonstrating and developing such technology is therefore important in maintaining a presence in such a highly strategic sector of technology.

Acknowledgements:

Dr. T.J. Hall of Department of Physics, King's College London for providing information of developments at King's College.

OPTICS

The Battle Between Source And Load

Importance of Source Resistance

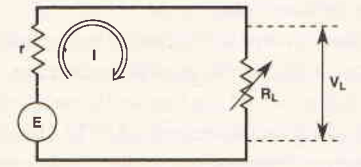


Fig.1 Variable load

by A P Stephenson

Any source of EMF has some internal resistance (or impedance) which sets an upper limit on the maximum current it can force through a closed circuit. If the source is a car accumulator, then both the finite conductivity of the sulphuric acid and the resistance of the lead electrodes make up the bulk of the internal resistance.

The result of short-circuiting a source of EMF with a screwdriver depends to a large extent on source resistance rather than voltage. A six volt dry torch battery, apart from getting slightly warm, may display no visible sign of distress but a six volt accumulator, subjected to the same indignity, may melt the screwdriver to the accompaniment of bangs and sparks.

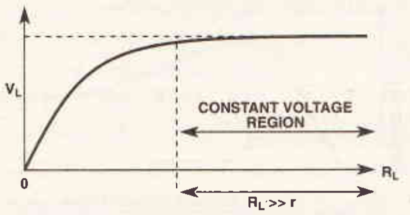


Fig.2 Effect of R_L on V_L

Although all high voltage sources of EMF should be treated with respect it is comforting to know that the lethal potential depends as much on the source resistance as the voltage. Under the right conditions, a girl running a comb through her hair at night is probably generating several thousand volts of static EMF but the equivalent source resistance of the hair —if dry enough to cause sparks—will be in the multi-megohm range so the current is unlikely to exceed a few nanoamps.

After all, it is current, not voltage, which causes the most trouble. Voltage represents energy in potential form —it only has the capability of doing something—whereas current represents energy in kinetic form and is actually doing it!

The Constant Voltage Source

Figure 1 shows an EMF (E) with source resistance (r) connected across a variable external load (R_L). The current flowing causes a voltage drop across the source resistance so the voltage across the load is less than the source EMF. Varying the load resistance will always vary the voltage across it but, providing the resistance is not allowed to fall below a certain limit, the variation can be negligable. This leads to the following definition:

An EMF source is acting as a 'constant voltage generator' if wide variations in the load resistance (or impedance) have minimal effect on the voltage across the load.

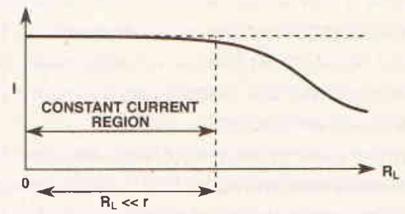


Fig.3 Effect of R_L on I

Although there is no upper limit on the value of the load resistance, it must always be much higher than the source resistance. Expressed in symbolism:

Providing $R_L >> r$, then E qualifies as a constant voltage source.

'Much higher' is, of course, a relative term but in practice, it can be taken to mean at least, ten times higher.

Here is a numerical example:

Let E=10 volts and r=10 ohms. Providing the load is never allowed to drop below 100 ohms, the load is being fed by a constant voltage source. That is to say, increasing the load from 100 ohms to several megohms, will not significantly alter the voltage (V_L) across the load.

It is worth checking a few values for R_L:

When R_L =100 ohms, V_L =10(100/110) =9.1 volts.
When R_L =1,000 ohms, V_L =10 (1000/1010) =9.9 volts.
When R_L =10,000 ohms, V_L =10(10,000/10,010) = 9.99 volts.

The graph in Figure 2, illustrating the effect of R_L on the load voltage, is based upon the basic voltage divider equation:

$$V_L = E \left[\frac{R_L}{r + R_L} \right]$$

When a load is operated by a constant voltage source, the voltage drop across r is small which means that R_L is approximately equal to E and the current approximately equal to E/R_L.

The term 'constant voltage' must not be taken too literally. It applies only if E is kept constant and RL is changed.

The Constant Current Source

In virtually all respects, this is the mirror image of the constant voltage source. The circuit and the symbolism of Figure 1 can still be used but the definition and the conditions are completely different.

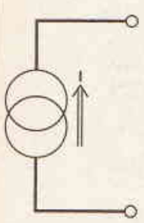


Fig.4 Symbol for constant current source

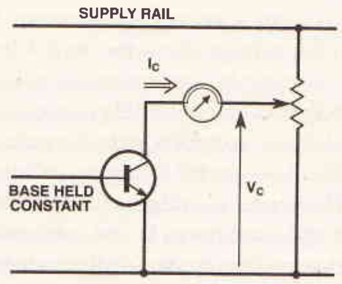


Fig.5 Constant current in transistor

A 'constant current source' is deemed to exist when the current through the load is virtually independant of the load resistance. The circuit conditions necessary to achieve this are as follows:

Providing the load resistance is always kept much smaller than the source resistance, the EMF will behave as a constant current source — well almost!

As usual, 'much smaller' is taken to mean at least ten times smaller.

Example: Assume E = 10 volts, r = 1,000 ohms and R_L = 10 ohms. The current will be $E/(r+R_L)$ = 10/(1,010) = 9.901mA.

If R_L is now decreased to 5 ohms, the current will be 10/(1,005) = 9.95mA.

Notice that even halving the load resistance had little impact on the current. The graph in Figure 3 illustrates the effect on the current of varying R_L.

A constant current source is often represented by the symbol shown in Figure 4. The current labelled I is assumed to be E/r because the load resistance must be assumed negligible in order to justify the use of the symbol.

Constant Current devices

Some components are constant current sources in their own right. For example, the collector current (Ic) in a junction transistor is substantially independant of collector voltage (Vc) over a wide range thereby qualifying it for such a title. The meter measuring Ic in Figure 5 will hardly move as the slider, used for tapping off Vc, is moved almost over the full range. The actual value of the 'constant' current depends on the setting of the base current.

The base/emitter junction of a bipolar transistor requires feeding from a constant current source, as does a light emitting diode.

The Maximum Power Law

The previous discussions have been concerned with massive inequalities between r and R_L. A constant voltage source required r to be much less than R_L whereas a constant current source required r to be much greater than R_L. However, if power in the load is more important than voltage or current then it is essential to ensure that R_L = r. This equality between source and load forms the basis of the following law:

Maximum power is dissipated in the load when the load resistance equals the source resistance.

The rigid proof of the law requires a little calculus but the following intuitive approach based on Figure 1 and the graph of Figure 6 sacrifices rigidity in return for simplicity:

1. If R_L is lower than r, the current is high but the voltage across it will be low due to the divider action between Vr and V_L.
2. If R_L is higher than r, the voltage across R_L is high, because of the more favourable divider action, but the current is low.

It is not unreasonable to hazard an intelligent guess that when R_L and r are equal, the current and voltage across the load will form the maximum product even if their individual values are less than maximum. Since power is equal to the product of voltage and current, the power in R_L will therefore reach a maximum when R_L = r. When this relation is satisfied, the load is said to be 'matched' to the source.

The graph in Figure 6 shows how the load power varies as the load resistance is varied. If the load resistor has a low power rating, it would be an interesting — although potentially hazardous — experiment to 'tune' it for maximum smoke!

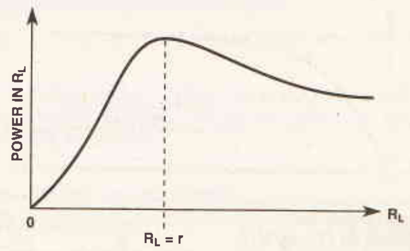


Fig.6 Effect of R_L on load power

Notice that the graph rises steeply at the left but falls away much slower as it leaves the maximum power point. There is a moral in this — if accurate matching is difficult, or inconvenient, it is better to err on the side of too high a load resistance rather than too small!

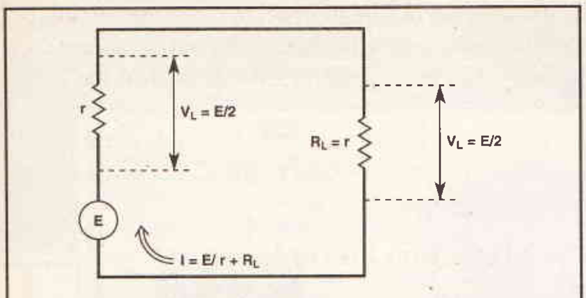


Fig.7 Voltage distribution under matched load conditions

Maximum Delivered Power

Under conditions of maximum power, the voltage (V_L) across the load is only half the source EMF (E) because the other half is squandered within the source resistance. This means that:

Power transfer = 50% under matched load conditions.

Armed only with E and r and a little algebra, it is possible to find the maximum power (P_L) any source can deliver to an external load. The following procedure is based on Figure 7:

$$P_L = V_L\, I_L = \frac{E}{2}\,\frac{E}{r + R_L} = \frac{E^2}{2(r + R_L)}$$

But, under matched load conditions, $R_L = r$ so we can write,

$$P_L = \frac{E^2}{2\,(2r)}$$

And simplifying, we arrive at,

$$P_L = \frac{E^2}{4r}$$

This is an important result and deserves a couple of examples.

1. A certain signal generator has an open circuit EMF of 10 volts at a source resistance of 50 ohms.
Maximum power it can deliver is:
$P_L = E^2/4r = 100/200 = 0.5$ watt.
If the load is not matched, the power delivered will be less than this figure.

2. A certain lead acid accumulator has an open circuit EMF of 12 volts at a source resistance of 0.01 ohm.
Maximum power it can deliver is:
$P_L = E^2/4r = 144/0.01 = 14.44$kW.

Warning! This example is of theoretical interest only. The accumulator would probably buckle its plates in rage at the prospect of supplying a matched load.

Source Impedance

The maximum power law, subject to certain modifications, still holds for alternating current circuits. Resistance, of course, must be replaced by impedance and the matching of load to source must take into account the phase angle.

If, for example, the source impedance is 100 ohms at a phase angle of 20 degrees leading, the load must be 100 ohms at a phase angle of 20 degrees lagging. Expressing this in vector jargon, the source and load impedances must be 'conjugates' of each other.

Example: If the source = $10 \angle 30$, the load must be $10 \angle -30$.

In general terms, if source is of the form z = (R+jX) then the load should be of the form z = (R-jX).

Power Transfer Efficiency

As explained earlier, a circuit operating under matched load conditions is only 50% efficient. This is the price that must be paid for demanding the highest power transfer. Fortunately, the need for such a wasteful procedure is normally restricted to the far end of electronic circuits. In the case of audio amplifiers, only the last transistors in the chain are obliged to disgorge their output into a pair of matched speakers while in ham radio, only the final tank circuits of the transmitter operate under matched load conditions.

Efficiency = (power in load)/(total power supplied)

So to achieve high efficiency, most of the power must be confined to the load. In turn, this means that R_L must be much greater than r which, as discussed earlier, happens to be the criterion for a constant voltage source! It is paradoxical that high power efficiency can only be achieved by putting up with low power.

Matching between source and load is often required for reasons other than power transfer. In coaxial transmission lines, the primary reason for matching is to prevent reflections and the resulting standing waves.

Surround Sound

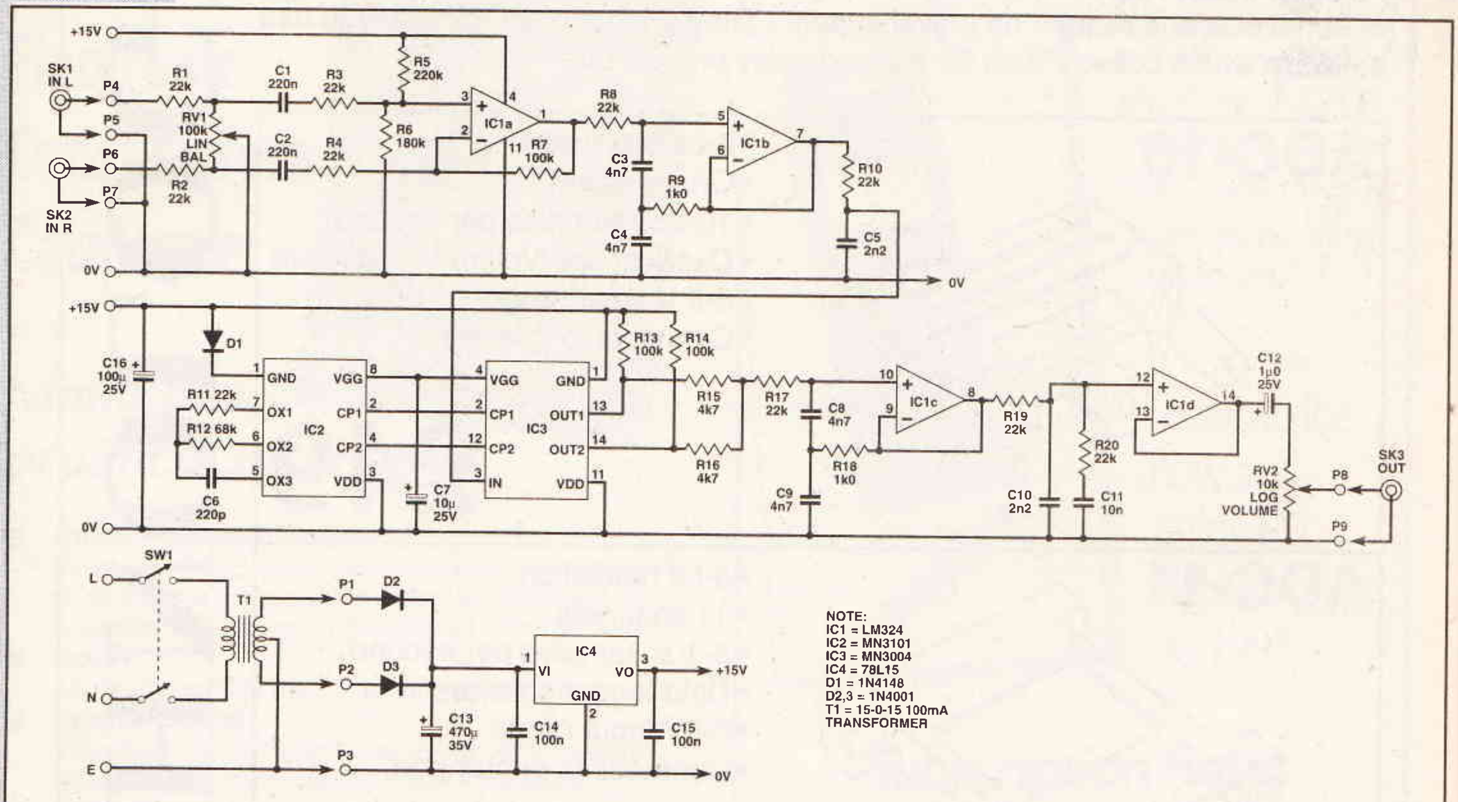


Fig.1 Complete circuit diagram of Surround-Sound decoder

HOW IT WORKS

The circuit diagram is shown in Figure 1. The input signals should be within the range 0.5 to 1.0 volts RMS, this is the usual level from the audio output (NOT Speaker) connectors on equipment. IC1a is the left minus right amplifier circuit, with a gain in differential mode of about five. This gain will overcome the loss caused by the balance control, and give adequate signal to drive subsequent stages. The Balance control, RV1, is used to offset any difference in the level of the two channels, this is will require fairly careful setting up in use, to reduce the amount of left and right channel signal from the rear channel.

R5 and R6 set the bias for IC1a and, since the circuit is directly coupled, for the delay and remaining op-amps.

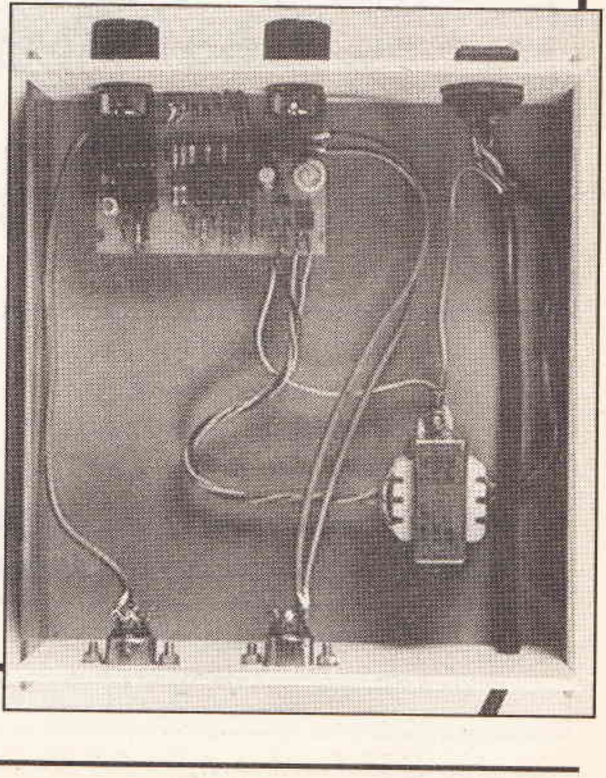
The extracted signal then passes through a low pass filter, built around IC1b, with a roll-off of about 18dB per octave, and the -3dB point a little below 4kHz. The signal then passes through an analogue bucket brigade delay line, with a delay of 16ms.

IC2 (MN3101) is the clock for the delay line, and produces two anti-phase square-wave signals, with a frequency of 16kHz, which gives a delay sampling frequency of 8kHz. The IC also generates a reference voltage for the delay line, which is decoupled by C7. IC3 (MN3004) is the delay line itself, and the two outputs from it are summed by R15 and R16.

This summed signal then passes through another filter built around IC1:c. This is similar to before, but with the addition of R20 and C11, which reduce the signal by about 6dB above 300Hz, effectively giving a little bass boost. The signal is then buffered by IC1d, and fed to the volume control via C12. The output from the volume control will then be connected to your power amplifier as required.

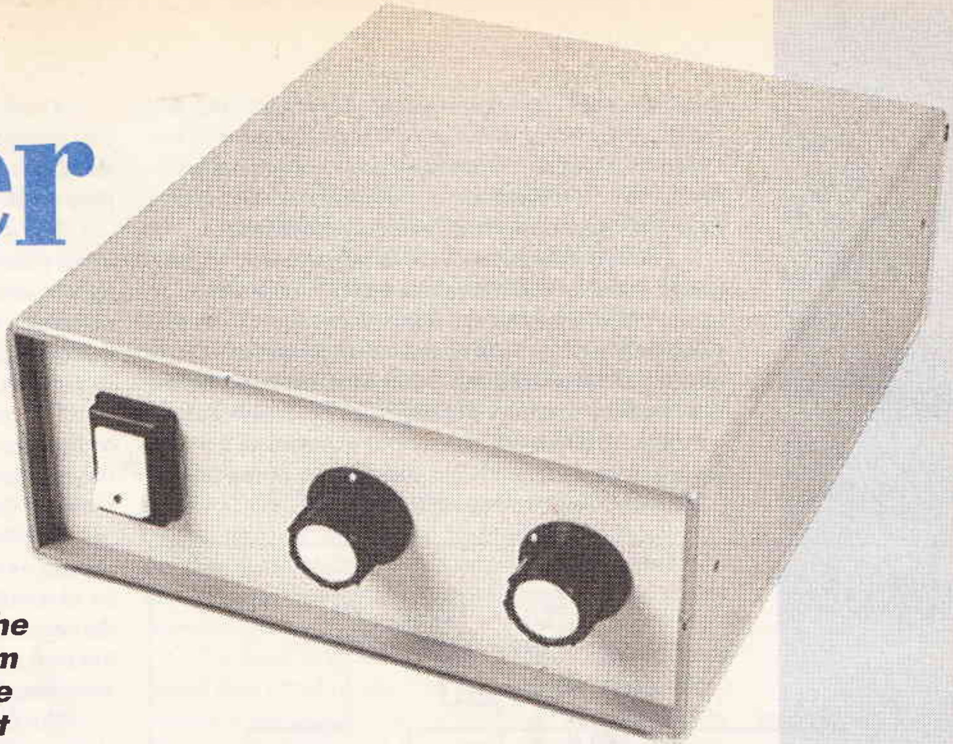
Please note that the frequency responses of the filter circuits have been calculated using analysis (Spice) software, based on the op-amp specified. Using a different device will give incorrect results, and may result in instability.

The mains enters via SW1, and passes to the transformer, T1. The output from the transformer is rectified by D2 and D3, and smoothed by C13, to give about 23V. The power supply voltage required is 15V, which is regulated by IC4.



PROJECT

Decoder



Paul Stenning extracts the rear sound channel from film soundtracks to give very stunning results at low cost.

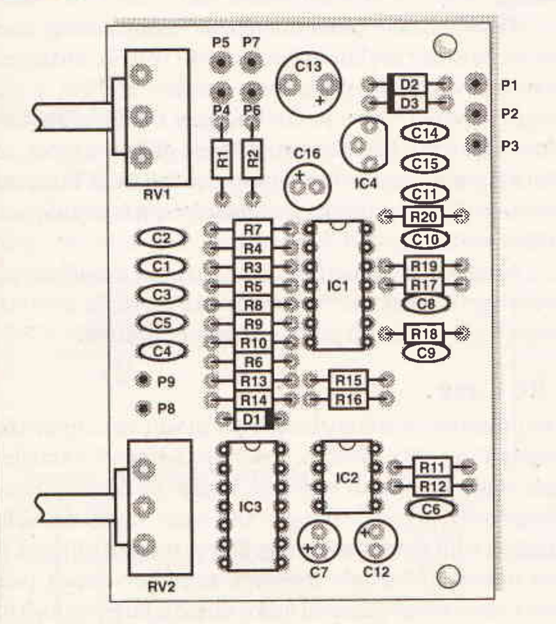


Fig.2 Component Overlay for decoder

Many owners of satellite receivers, Nicam Stereo equipment and stereo video recorders are taking advantage of the vast improvement in realism that can be obtained on stereo film soundtracks, by feeding the sound through the Hi-Fi, and positioning the TV centrally between the speakers.

However, by comparison to the cinema, there is still something missing! Apart from the large screen and the kids throwing popcorn around, an important absense at home is the Dolby Stereo surround-sound system. Many films are now made with Dolby Stereo sound, and if it says "Dolby Stereo in Selected Cinemas" at the end of the credits, the surround sound information will still be encoded into the stereo soundtrack whether the film is transmitted by satellite or in Nicam stereo, or released on video.

There are some excellent Dolby licensed decoders available for home use, however these tend to be rather expensive. The unit presented here is a "sound-alike" circuit which, whilst not performing as well as the real thing, still gives superb results for a more affordable price. Since the PCB is supplied with this magazine, and the components (including a case) can be obtained for under £30, this project is a must for any film fan with satellite, NICAM or a stereo VCR. The only other requirements are a small amplifier and a pair of cheap speakers. Some constructors may wish to incorporate a power amplifier circuit in the same case as this decoder, suggestions for this are given later in this article.

The project is quite straightforward to assemble and requires no setting up, so should be well within the capabilities of most constructors. To this end, detailed assembly instructions will be given (more experienced constructors please bear with us!), and component colour codes or markings are given in the parts list.

Surround Sound: The Operation

When the film soundtrack is recorded, the surround sound channel is encoded by first filtering it and attenuating it by 3dB, and then passing it to two phase shifting circuits. One of these shifts the signal by +90° and sums it to the left channel, the other shifts the signal by −90° and sums it to the right signal. Thus the signal is 180° out of phase between the two channels.

To extract the signal, basically all that is required is a fixed left minus right network. However, for better realism the extracted signal requires additional processing in the form of a short delay, typically between 12ms and 25ms, in this case 16ms. The purpose of the delay is to make any front channel sounds that stray to the rear channel, less noticeable. This is achieved by confusing the ear; since any stray sounds will come from the front channels a few milliseconds before the rear, they will appear to originate from the front. The delay also gives the sound more depth. A similar delay is also used in licensed Dolby decoders, and is allowed for by the film makers.

A low pass filter comes before the delay circuit to limit the bandwidth of the signal to just below 4kHz, half the delay sampling frequency (8kHz). The delay is followed by a similar circuit to remove the sampling frequency from the signal. In addition, this filter also gives a degree of bass boost (+6dB below about 300Hz).

Limiting the bandwidth in this way does not significantly detract from the performance of the unit. The bandwidth of the surround signal in a proper Dolby system is only 100Hz to 7kHz, and the upper end of this can only be achieved by using Dolby licensed noise reduction circuitry to remove stray signals. The surround channel exists for effect, not for listening to in its own right. So as long as the Left and Right channels are of reasonable quality the overall result will be fine!

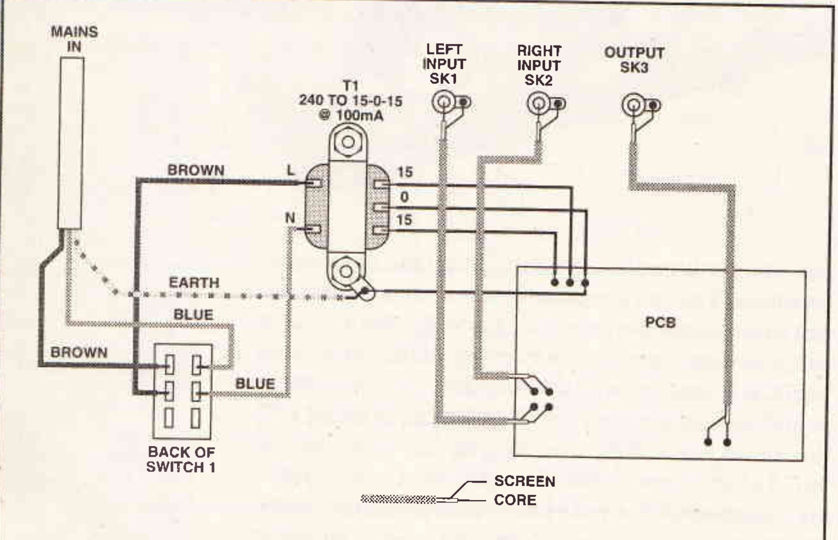


Fig.3 Inter wiring diagram

PCB Construction

The PCB for this project is supplied on the front cover of this magazine. Additional PCBs may be obtained from the ETI PCB service, see page 76 for details.

In order keep costs down, the PCB is supplied with all holes drilled to one size. Before starting assembly, the sizes of the following holes should be checked and enlarged if necessary. Holes for RV1 and RV2 need to be enlarged to 1.2mm (alternatively wire these components to the board using short lengths of 24 SWG tinned copper wire). Holes for the terminal pins P1 to P9 may need to be enlarged to 1.0mm (alternatively solder wires straight to the board without using terminal pins). The holes for diodes D2 and D3 are a close fit, and may need to be enlarged to 1.0mm.

The component overlay for the PCB is shown in Figure 2. Double check the position, value and orientation of each component, against the overlay and Parts List, before soldering it into place. Take care when soldering, to ensure reliable joints. In particular take care where tracks pass close between pads, to avoid solder bridges.

Start by fitting the resistors, these components can be fitted either way round. The colour codes are given in the parts list. If the resistors used have a tolerance better than 5%, the Gold band will be Brown (1%) or Red (2%).

Next fit the diodes. These must be fitted the correct way round, as shown on the Overlay.

The IC sockets should then be fitted. Again orientation is important, the notch in the centre of one end should be positioned as shown on the Overlay. Do not plug the ICs into the sockets yet.

The terminal pins (if used) should be inserted now, in the positions marked P1 to P9. These will be a fairly tight fit and should be pressed firmly but carefully into place with the soldering iron. Support the board whilst doing this, and check the pins are properly in place and straight before finally soldering.

The ceramic capacitors can be fitted next, these can be fitted either way round. The values of these may be shown in a variety of ways, the most likely markings are shown in the parts list.

The electrolytic capacitors can be fitted now. Polarity is important, the positive connection is shown on the overlay with a +. On most electrolytic capacitors, the negative connection is marked with a –, and the positive lead is the longer one. Fit with the negative marking away from the + on the overlay.

The voltage regulator, IC4, is fitted next. Orientate as shown on the overlay, and gently push down until the base of the body is about 5mm above the PCB before soldering.

Finally fit the potentiometers. Before fitting, trim the shafts to suit the knobs being used. Grip the end of the shaft (not the body of the pot) in a vice, and cut to the length required with a junior hacksaw, then remove any burrs with a fine file. The two pots are different types, so check the markings before fitting into the PCB. Push the pots well down and make sure they are correctly aligned before soldering.

Now give the board a thorough visual examination, checking in particular for incorrectly placed components, badly soldered joints and solder bridges.

The Case

The prototype was constructed in a plastic case, approximately 170 x 70 x 190mm, however a somewhat smaller case could be used if required. Since the unit contains dangerous (mains) voltages the case must be held together with screws, a clip together case is not suitable. If you intend to include a power amplifier circuit (see later), use a metal case and make sure it is large enough to house all the components comfortably.

Since the PCB is so small and light, it will be perfectly secure mounted by the potentiometers, unless the unit is to receive some particularly rough treatment! Two holes are required in the front panel for the pots, 2 inches apart and the right diameter for the bushes on the pots being used. If the small PCB mounting pots from Maplin are being used, the holes need to be 7mm (9/32") in diameter. If the pots have any small lugs to locate into the panel, these can be carefully cut or broken off.

A third hole will also be required on the front panel, to suit the power switch being used. The switch used on the prototype was supplied by Maplin as a Miniature Rocker Switch (YX65V), and required one 18mm diameter fixing hole, and a small notch to prevent rotation. It may be easier to use this type of switch, rather than one which requires a rectangular cutout.

The front panel can then be marked with rub-down transfers and sprayed with lacquer if desired, before the components are fitted. When tightening the pot nuts, support the body of the pot from behind, and do not over-tighten. The washer should be placed against the front panel, behind the nut. The suggested switch has a plastic nut which should only be tightened a little more than finger tight. The knobs can now be fitted, ensuring they do not scrape on the panel.

The rear panel can now be prepared, with a hole for the mains cable grommet or clamp, and appropriate holes for the audio connectors being used. The prototype has 5 pin DIN sockets, however phono sockets would probably be more suitable in most setups. You may prefer to use two sockets each for Left Input and Right Input, connected in parallel, to save using Y splitters or making custom cables (see the Installation Diagram, Figure 4). The same could apply for the output if using a stereo amplifier, so the signal can be taken to both channels.

The transformer should be mounted in the base of the case. Mount it away from the circuit board and audio connectors, but where the leads will still comfortably reach the board and switch. Fit a solder tag under one of the mounting nuts for the Earth connection, having scraped away any lacquer from around the hole in the transformer first. The prototype used a 100mA wire ended transformer, which was more than adequate for the job.

Wiring Up

The Interwiring Diagram is shown in Figure 3. Start with the audio connections, using suitable screened cable. If you wish to sleeve the screens, use a piece of the outer insulation removed from the wire. If two phono sockets are being used for the inputs and/or output, as suggested earlier, they can be linked together with lengths of tinned copper wire, providing the sockets are no more than about 40mm apart.

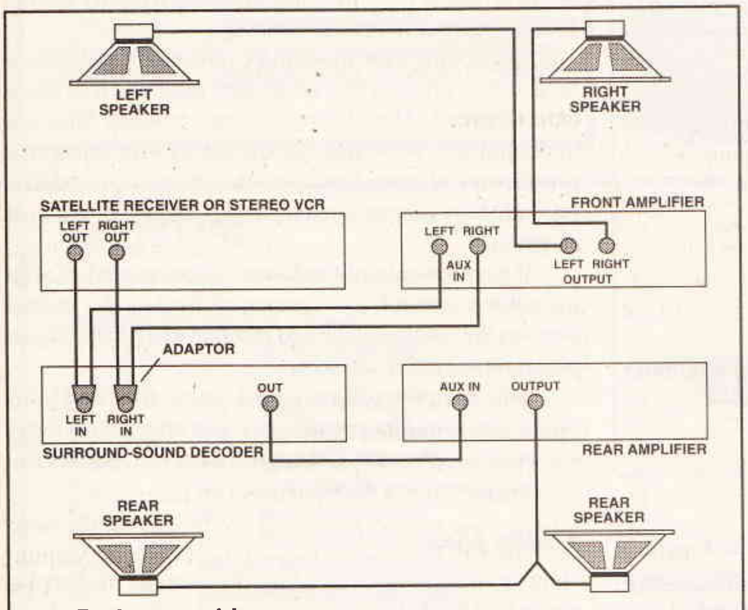


Fig.4 Equipment wiring

Connect the 'Left Input' socket to P4 (core) and P5 (screen) on the PCB, the 'Right Input' socket to P6 (core) and P7 (screen), and the 'Output' socket to P8 (core) and P9 (screen).

The mains wiring should now be carried out, with great care! Mistakes here can be costly and dangerous.

The mains cable is standard 3 core mains flex, rated at 3 Amps or greater. A grommet or cable clamp must be fitted in the hole where the mains cable enters. The cable must be secured in some way. As a last resort you could tie a knot in the cable, but try to do something better.

Remove sufficient outer insulation for the earth (Green/Yellow) wire to reach from the switch to the tag on the transformer mounting. Trim the Live (Brown) and Neutral (Blue) wires to about 30mm, strip the ends, and solder to the switch as shown in the Interwiring Diagram, ensuring that there are no loose strands. These joints should be sleeved for safety.

The thick Brown and Blue wires from the transformer primary should now be soldered to the switch, as shown in the Interwiring Diagram, and sleeved as before. To save possible damage to the transformer, leave these wires the full length as supplied.

The Earth (Green/Yellow) wire in the mains flex should now be soldered to the tag under the transformer mounting nut, together with a length of wire sufficient to reach the PCB. If the case has a metal front panel, a wire should be connected from this to the earth tag (a metal rear panel will probably be earthed by the connectors mounted on it, if not connect it to the tag also). It may be easier to remove the tag whilst soldering. Recheck the tightness of the transformer mounting screws after soldering these joints.

The wires from the secondary of the transformer will be two of one colour (possibly Green), and one of another colour (probably Black). Connect the single wire, together with the wire from the transformer earth tag, to terminal P3 on the PCB. Connect the two same colour wires to terminals P1 and P2 on the PCB, either way round. As before, it is best to leave the transformer wires full length.

Connect a 13 Amp plug, fitted with a 3 Amp fuse, to the end of the mains flex.

Now thoroughly recheck the wiring, particularly the mains connections. Remember that any mistakes in the mains wiring are potentially lethal.

Testing

Before plugging the unit in for the first time, carry out the following tests. Make sure the power switch is off. Set your test meter to its highest resistance range, and measure the resistance between Live & Neutral, between Live & Earth, and between Neutral & Earth on the mains plug pins. In all cases the meter should read open circuit.

Now set the power switch to ON and carry out the above tests again. The resistance between Live & Neutral should now be between 1k and 2k (transformer primary), the other two tests should still read open circuit.

Set your test meter to the lowest resistance range available, and measure the resistance between the Earth pin on the mains plug and the following points: both transformer mounting screws, the screens of all audio connectors, and any exposed metal parts of the case. In all cases the meter should read less than one ohm.

If any of the above results are incorrect, recheck your wiring thoroughly and find out why! It is fairly easy to incorrectly wire a mains switch so that it shorts across the mains when switched on. Do not plug the unit into the mains until the results of all the above tests are correct.

Ensure that the plug-in IC's (IC1, IC2 and IC3) are not fitted. Plug the unit into the mains and switch on. Set your test meter to 30 Volts DC or greater, and connect itüs negative probe to the earth tag on the transformer. Connect the positive probe to the cathode (bar) end of D2 or D3, the meter should read between 20V and 27V. Now connect the positive probe to pin 3 of IC1 socket, the meter must now read between 14.25V and 15.75V.

If all is well so far, switch off and wait five minutes, for the power supply smoothing capacitors to discharge. Now plug in the ICs, and switch on. Measure the voltages at the following points: IC1 pin 1, IC1 pin 7, IC3 pin 13, IC3 pin 14, IC1 pin 8, and IC1 pin 14. In all cases the voltage should be between 5 and 7 volts (it may be necessary to switch your meter down to its 10V DC range for this). Switch off and assemble the case.

Now install the decoder and test out, as detailed below.

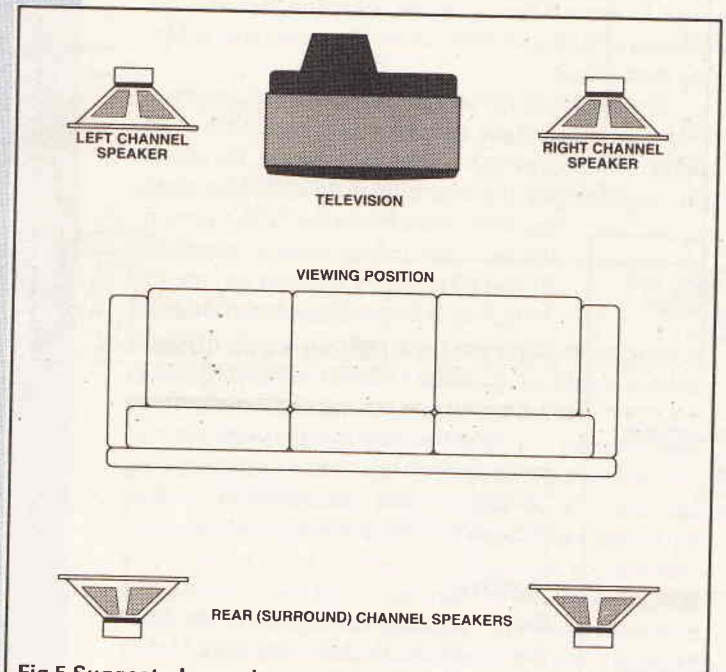


Fig.5 Suggested room layout

Installation and Use

The ideal viewing room setup is shown in Figure 5, although some compromises may well have to be made in practice. Two rear speakers are really required, if only one speaker is used its position will be heard. These speakers should be behind the viewer, towards the rear corners of the room. The effect is a little better if the rear speakers are further away from the viewer than the front speakers. Remember that the rear speakers do not have to be of particularly good quality, since the rear channel bandwidth is only 100Hz to 4kHz. The author used a pair of small wooden cased speakers which originated from a stereo music centre, and a low power stereo amplifier. His supply of Dolby Stereo films arrive via an Amstrad SRD400 satellite receiver.

Connect the unit to your home entertainment equipment, as shown in Figure 4. Note that the Audio Out from the satellite receiver or VCR needs to connect to both the decoder and your main amplifier, this is the reason for the suggestion of paired sockets. Set RV1 central and RV2 to minimum. Leave the main amplifier off for now, and switch on the surround amplifier, this unit and the satellite receiver or video recorder.

Choose a mono program (if you have satellite try Sky News), and turn up the volume control (RV2). If the balance control (RV1) is adjusted towards either end the sound should be heard from the rear speakers. When the balance control is adjusted towards the centre it should be possible to find a point where there is virtually no sound from the rear speakers.

Leave the balance control at this position, and select a stereo film channel (Sky Movies or The Movie Channel). If the film is in Dolby Stereo, you should get a significant amount of sound (but not speech) from the rear channel. If you can't get this to work, check your satellite receiver is set to the main stereo channel (AU1 on Amstrad receivers), and check the film really is in Dolby Stereo (the blockbusters shown on Sky in the evenings often are).

Switch on the main amplifier and set the volume to your usual listening level. Now adjust the level of the rear channel to a level where the rear sounds contribute to the overall sound, without intruding. Dialogue should still appear to come from the front, whilst crowds, music and dramatic sound effects should fill the room.

A certain amount of practice will be needed to get the best results from the unit, it's really a matter of trial and error, but it's worth the effort!

The results from this simple unit can be quite stunning, it really does add a whole new dimension to home entertainment. The effects on some modern films are dramatic! Sky Television are obviously well aware that people use this sort of equipment, since even the trailers on their film channels make very good use of the rear channel.

If your main amplifier has an output available, after the volume control, try connecting the decoder to this, that way the volume of the rear channel will follow adjustments on the main amplifier.

This decoder will only work correctly with Dolby Stereo encoded film soundtracks. The effect of the delay will cause awful results if the unit is used with normal stereo programmes or music.

A Silly Idea!

Here's a further idea that a few of you might like to play around with. If the decoder is used without the front amplifier, on a normal stereo music source, the balance control can be adjusted to give the music in mono with little or no vocals. Do-it-yourself Karioke for those who like that sort of thing! Of course the bandwidth is very limited and the bass beat may be cancelled out as well, but it will probably still sound better than the singing!!

Adding a Power Amplifier

The information in this section is believed to be correct but has not been fully tested. It is therefore offered to more experienced constructors, for further experiment.

Some constructors may wish to incorporate a power amplifier into the same case as this decoder.

As only a few watts of power are generally needed for the rear channel, a suitable amplifier might be the Maplin 8 Watt Power Amplifier kit (LW36P, Price £7.45, Page 292 of the 1992 catalogue). This requires a power supply of about 21V, and a suitable circuit is shown in the catalogue, this could be constructed on a piece of tag strip or Veroboard.

It would be sensible to use the amplifier's power supply to power the decoder circuit. On the Surround Sound Decoder PCB, remove D1 and D2, and replace D1 with a link. The 21V form the amplifier power supply can now be connected to P1 (positive) and P3 (negative). If a different amplifier is used, a supply between 18V and 35V can be used to power the decoder this way.

The audio output from P8 and P9 can be connected directly to the amplifier input, using suitable screened cable. If you get a hum loop, try disconnecting the screen at the amplifier end. It may be necessary to reduce the gain of the power amplifier, by adjusting the values of the appropriate resistors on the amplifier PCB. A suitable connector or terminals for the loudspeaker can be fitted on the rear of the case.

Unless continuous operation at high volume is likely, a metal case should be adequate for heatsinking the amplifier and power supply voltage regulator.

BUYLINES

The PCB is supplied with this issue of ETI, further PCB;s are available from the ETI PCB service, if required.

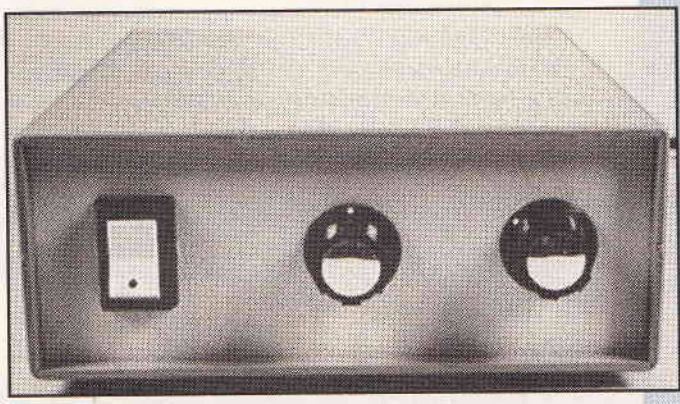
The majority of the components should be readily available from your usual component supplier. If any problems are experienced, all the components are listed in the current Maplin catalogue (telephone 0702 554161).

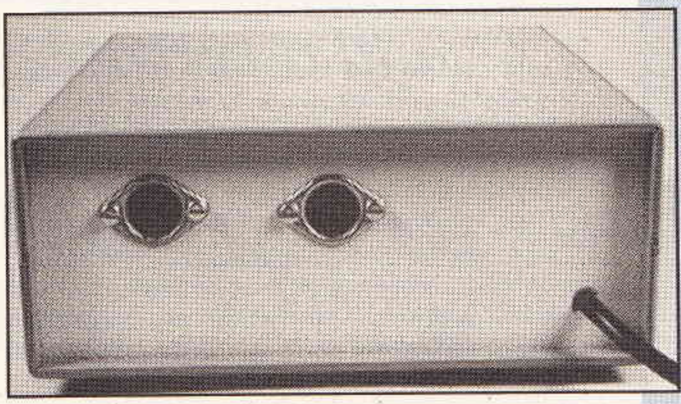
ACKNOWLEDGEMENTS

Dolby, Dolby Stereo, Dolby Surround and the Double-D Symbol are trademarks of Dolby Laboratories Licensing Corporation. This project is based on generally available information and to the best of the authors knowledge does not infringe any of Dolby's patents.

All other trademarks acknowledged.

Some aspects of this project are based on information from an article by Robert Ball in Electronics — The Maplin Magazine, Issue Number 37.





PARTS LIST

Part Number	Value	Markings
RESISTORS (All 1/4 watt 5% or better)		
R1,2,3,4,8,10, 11,17,19,20	22k	Red Red Orange Gold
R5	220k	Red Red Yellow Gold
R6	180k	Brown Grey Yellow Gold
R7,13,14	100k	Brown Black Yellow Gold
R9,18	1k0	Brown Black Red Gold
R12	68k	Blue Grey Orange Gold
R15,16	4k7	Yellow Violet Red Gold
RV1	100k LIN	B-100k (min PCB mounting)
RV2	10k LOG	A-10k (min PCB mounting)
CAPACITORS		
C1,2	220n	224
C3,4,8,9	4n7	472
C5,10	2n2	222
C6	220p	221
C11	10n	103
C14,15	100n	104
ELECTROLYTICS		
C7	10µ	25V
C12	1µ0	25V
C13	470µ	35V
C16	100µ	25V
SEMICONDUCTORS		
IC1	LM324	
IC2	MN3101	
IC3	MN3004	
IC4	78L15	
D1	1N4148	
D2,3	1N4001	
MISCELLANEOUS		
P1-9	Terminal Pin	
SW1	DPDT Rocker Switch	
SK1,2,3	Phono Socket (or as required)	
T1	240 to 15-0-15 100mA	

IC Sockets (1x8 way and 2x14 way), Case, Knobs for RV1 & RV2, Mains Flex, Screened Cable, Sleeving, Fixings for T1, Solder Tag, Grommet or Cable Clamp, 13A Plug with 3A Fuse, Audio Connection Leads as Required.

Camera add-on Tri

Add a versatile sound and light trigger t

This two-board project has been designed with those who are as handy with a soldering iron as they are with a camera. The project will provide a useful addition to the facilities of any SLR camera with simple interfacing through the cable release socket. It allows electronic signals to trigger your camera giving timed exposures beyond the end of the basic range which is usually in the 1 second region. But it also allows you to program how many exposures are taken.

Looking more closely at the two basic output functions that are catered for; firstly there is programmable multiple triggering at adjustable rates, that is, setting the camera to take a set number of photographs with differing delays between the exposures. Secondly a timer facility that allows exposures from 1 second to 100 minutes, thus allowing long accurate exposures without the hassle of having to monitor them. Programming the exposure time is done simply by a single push switch, and the result is displayed on seven segment display, as is the countdown operation.

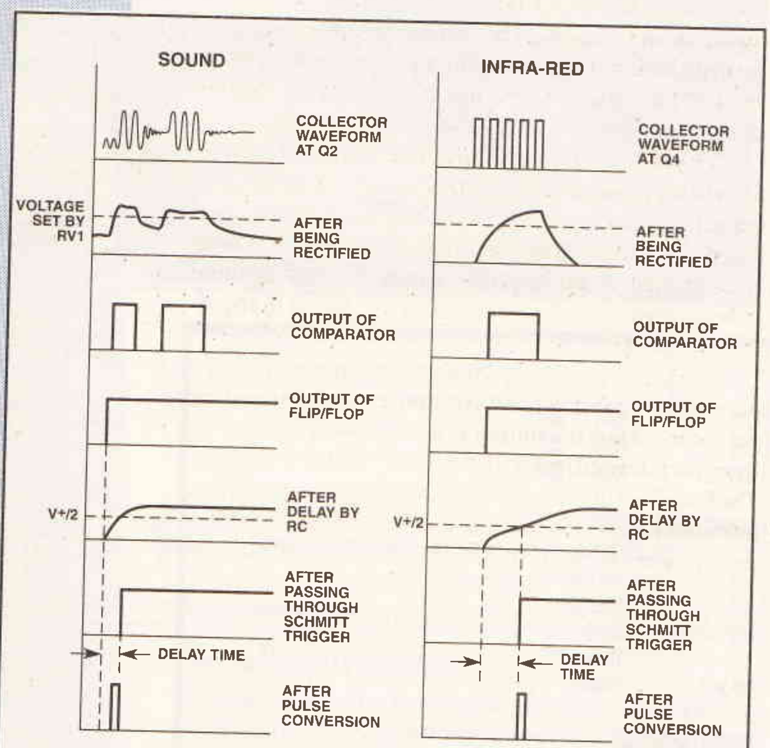


Fig.1 Timing waveforms

One of the unique features is the form which the triggering of both of these functions can take. There is a microphone operated sound triggered input which can be set to trigger at differing sound levels, from a bump in the night to a snap of the fingers or a simple clap. Secondly there is an infra-red link which allows either the breaking of a beam or the formation of one to trigger the camera. Again the trigger levels can be set as with the sound input. Both of these functions can be used as a convenient replacement for self timers allowing the user to be in the photo, and taking it when they feel comfortable by simply making a loud noise, 'Cheese' perhaps. Provision has also been made for two external inputs to act as triggers, one has been designed to accept a simple push-to-make switch as a signal generator, a more conventional format. The other input will accept analogue voltage signals and convert them to binary in the same way as the other two analogue signals, with presetable trigger levels.

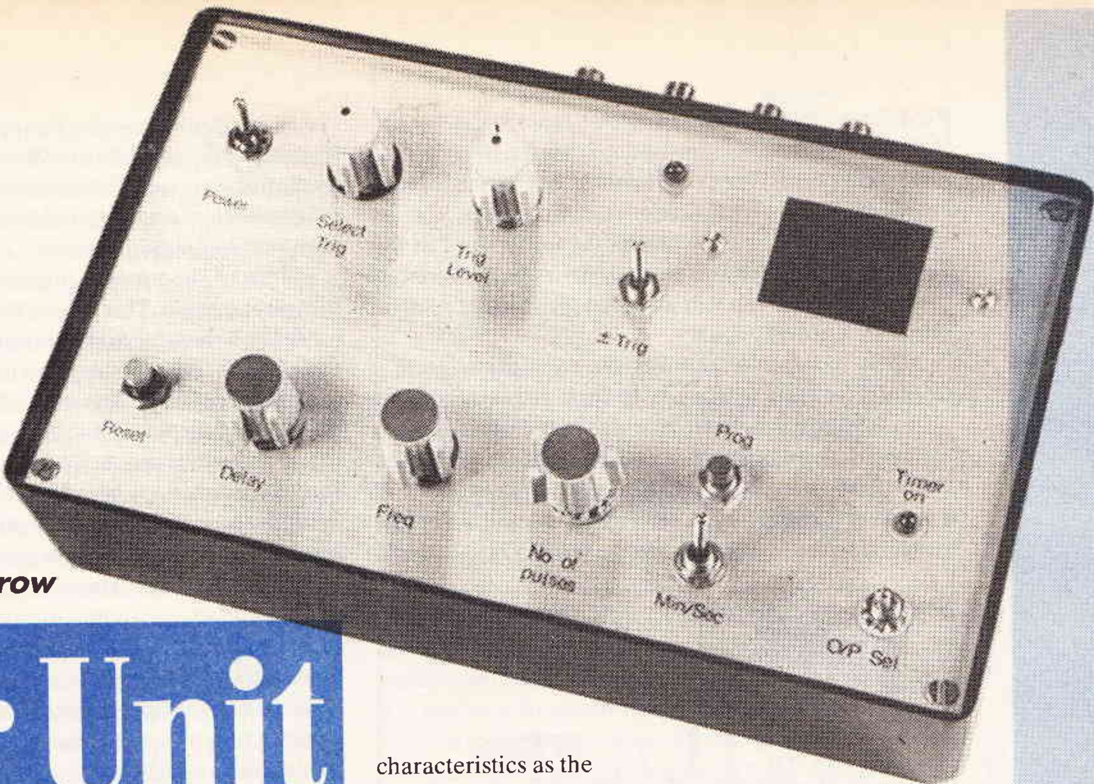
A light emitting diode shows when triggering occurs and allows easy setting of the required levels. A slight variable delay can be placed on triggering which can be used to allow the subject or object time to move in towards the centre of view and away from messy wires, infra-red LEDs etc, before the picture is taken.

The unit has been designed to be mains powered but also has the facility to be driven by external batteries. Interfacing with the camera is easiest with electronic cable releases but it is by no means impossible to interface with manual cable releases.

Theory

It is best to visualise the circuit as consisting of three blocks, the trigger circuit, the multiple exposure circuit, and the timer circuit. A block diagram in Figure 5 shows a simplified schematic of the workings and can be consulted while reading this section. The first of these blocks, the trigger, starts life with a basic carbon microphone. This by its virtue of only being a resistor that changes its resistance with varying sound levels. It needs a source of current to produce a usable signal. The answer is a pull-up resistor. The 'not-too-large' signal is amplified by a simple self biasing common emitter transistor amplifier Q4, the circuit being more simple than the name, which is adequate as this is not a hi-fi project. After decoupling, this resulting signal is buffered by an emitter follower Q5, biased so as to compensate for the diode drop of the transistor and the following diode. It also provides some voltage to raise the floor above zero volts. This must be performed as the circuit uses a single positive supply line and inputs of comparator-like chips cannot operate at zero volts. The output of the emitter follower is then rectified and smoothed, with provision made for a fast rise time and a reasonable decay. This conditioned signal triggers the sound input.

The story for the infra-red link is pretty much the



by Edward Barrow

gger Unit

to your camera

same, with an infra-red sensor providing the necessary raw signal, but as before not much of it. This circuit only responds to modulated infra-red radiation and so the initial decoupling capacitor removes any constant signal that may be generated from a background source. Again the first stage is a self biased common emitter amplifier Q1. More gain is required and a second stage around Q2 is adopted. After decoupling and buffering by another common emitter amplifier, biased again for the same reasons, the signal is rectified by a rectifier of similar characteristics as the sound input. A suitable source of infra-red is discussed later on in the article.

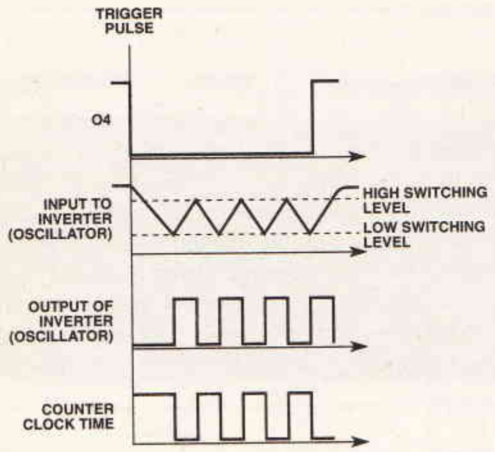
All the inputs are fed to a rotary switch and one of these is selected by the rotary switch SW3. This feeds the positive input of the comparator which has been wired to have some element of positive feedback necessary to ensure clean switching. The variable reference point for the negative input is provided by a 'pot' acting in a voltage divider. This allows triggering to be set at the desired level.

The two external inputs are merely external connections to the positive input of the comparator, the first one requiring a short-circuit between the two leads to generate an input pulse. This is self explanatory as one of them is connected to the positive supply. The other input requires a voltage signal relative to its ground to trigger the comparator.

For the sake of completeness the comparator's output has been inverted and this output can be used as a trigger source. Thus the output will trigger when either the sound or infra-red level falls below the set threshold level. The benefit of this arrangement is mainly in the use of the infra-red link, as the unit can then be used to trigger the camera when the beam is broken. This is a useful feature for nature photography where the camera can be set up to take photographs when an animal breaks the beam.

The analogue nature of the inputs give rise to the problem of noisy outputs or multiple triggering. This is caused when the input to the comparator hovers and fluctuates around the switching threshold. The positive feedback does reduce this significantly but does not eliminate the problem fully. A flip/flop is the cure, with the comparator's output being used as the clock source, and the data input being tied high. So only the first pulse from the comparator will get a response from the flip/flop. This means it will clock in the high state of the data input which will then appear at the outputs. To clear the flip/flop a reset button has been built in, which as the name suggests is only a push-to-make switch. It is tied high to generate a pulse for the reset pin.

The raw output of the flip/flop is not used as it is.



	f/4	f/5.6	f/8	f/11	f/16
WELL LIT BULDING, NEAR	1 sec	2 sec	5 sec	10 sec	30 sec
WELL LIT BUILDING, FAR	8 sec	16 sec	40 sec	80 sec	2.3 min
DARK STREET	4 sec	8 sec	16 sec	40 sec	90 sec
MOONLIGHT NIGHT	1 min	2 min	4 min	10 min	20 min
OVERCAST NIGHT	4 min	8 min	16 min	32 min	64 min

Fig.2 More timing waveforms and exposure times

Firstly some delay is injected with a simple R-C delay, the R part being a variable resistor, making the delay presetable. After buffering by an invertor the signal is pulse converted by another R-C combination, and this triggers the other parts of the circuit. As the buffer used in the delay part of the circuit is an invertor, it was the inverted output of the flip flop that was used (O), the net result is therefore a normal signal.

The next block controls the multiple triggering facility. The heart of this is a 10 stage Johnson counter (IC5). A rotary switch selects which output stage is going to be used. To understand the operation of this part of the circuit it is best to glance at the timing diagram in Figure 2. Let us say that the output selected is O4 and we've just switched on the power to the circuit board. O4 will be low

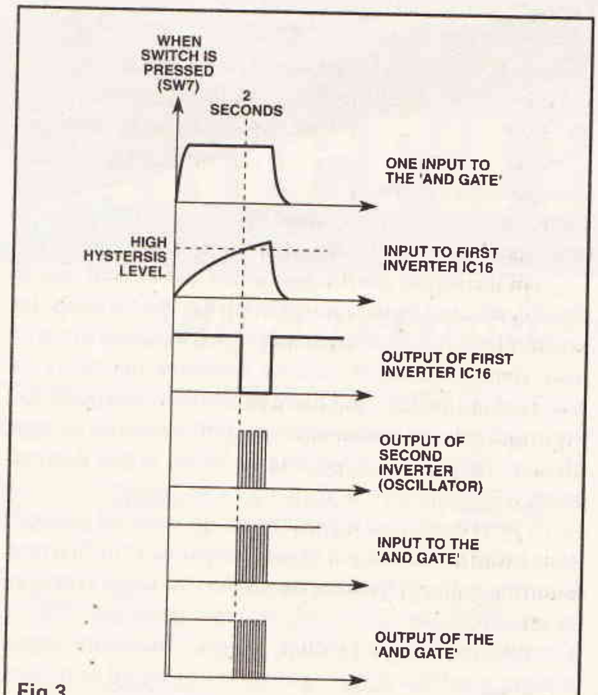


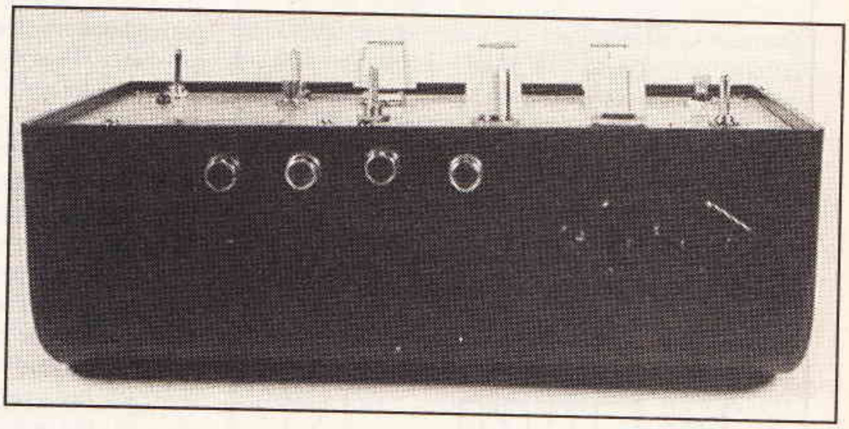
Fig.3

and so no current will flow through the diode (D6) as it is reversed biased, and hence the Schmitt trigger invertor IC3c will be left to its own devices. Here it is configured as a feedback oscillator, with its frequency being a product of the values of the feedback resistance and the capacitance of C14. The resistance is variable and hence so is the frequency. As the input to the invertor starts at the zero state, its output is high thus making the output of the NOR gate IC6c low to begin with, (the other input to the NOR O4 being low). When the invertor changes state its output goes low thus changing the output state of the NOR gate to high. While O4 is low, clock pulses are passed on to the clock input of the counter. This advances the counter with each negative going edge, ie one that goes from high to low. After four such pulses O4 will go high, this has two knock-on effects. Firstly it drives the output of the NOR gate low regardless of its other input. And secondly it forward biases the diode D6 so that the input of the invertor is tied high thus stopping the oscillation process. Importantly,the first series of pulses that are generated when power is first switched on, the initial state of the invertor input is now high and output thus low.

To start the process, a positive pulse is sent to the memory reset pin. This drives all the outputs low including O4 and since the invertors output is also low, the output of the NOR gate immediately goes high. When the invertor eventually starts to oscillate, the same scenario as before takes place, with four pulses being generated before all activity ceases. The first pulse has a longer duration than the others because the invertor needs time to pull the capacitor from its forced high state to the mid levels about which oscillation takes place. The NOR gate output is used as the trigger for the camera.

The timer circuit requires certain signals for operation, the most important being reference signals, ie. time-bases allow accurate measurements to be taken. Here the signal source is a crystal oscillator, built using an invertor to make a resonance circuit around a timing crystal. The frequency of the crystal chosen is 4.194304MHz, a convenient number for digital purposes as 2^{22} is 4194304 exactly. So if we divide this frequency by 2 twenty two times we get a 1 second clock exactly. As is well known dividing by two is very easy with the help of a flip/flop. In fact some helpful electronic engineers have already designed a counter with not just 22 but 24 flip/flops all linked up, and they even throw in an invertor to make the crystal oscillator, this is the 4521 (IC7) giving us a reference source already.

The timer unit should also count in minutes so a second time-base is needed, this time in minutes. The most logical way to generate this would be to divide the 1 second time base by 60. A dual BCD counter did the trick (IC8). The first BCD stage was left to free run thus dividing by 10. The second BCD stage acted as a divide by 6, and when both are combined they give a grand total division of 60, and thus a 1 minute time base.



The main counting operation centres around a pair of programmable up/down counters (IC11 and 12) and to help understand the timing diagram, Figure 4 has been included. One is assigned to the task of counting units and the other tens. Both are operated solely as down counters, ie they decrement by one with every clock pulse. The outputs of both of these chips are fed into a pair of BCD to seven segment decoders, which in turn feeds a pair of seven segment LED displays. These allow the state of the counters to be known easily. The counter has two inputs, one from the selected time base (seconds or minutes), this input is turned on when a trigger pulse is sent to the timer board. The other input comes from a manual pulse generating circuit which generates a single pulse every time a push switch is depressed and a series of pulses if the switch is held down for a period longer than 2 seconds. A glance at this part of the circuit may make you think that I settled for an ad-hoc solution to the problem but take a look at the 'How it Works' section for a further description. This is used to program the counters by counting them down to the required time using this push switch. The 'tens' clock input is linked to the units terminal count output (TC), which synchronises both counters. When the counter reaches the zero state this line goes low and returns high as the counter advances to the ninth state. Its on this positive edge that the 'tens' counter decrements.

When both terminal count lines are low this corresponds to the end of counting operations as both counters read zero. This state is used to clock a flip/flop whose data line is held high, so when the 00 state arrives, the flip/flop's output state changes. When a new trigger pulse arrives, signalling the start of counting, the flip/flop is reset and so the inverted output goes high until the 00 state. This delay, between the changing of states, is the required time pulse and so it is the inverted output of the flip/flop that is used to trigger the camera's shutter.

Construction

Perform the usual operations here. Solder resistors, link wires, and diodes first, then transistors, IC sockets and capacitors second. The external bits and pieces like pots, LEDs, rotary switches are placed lastly. The PCB connections for the rotary switch SW6 was designed so that ribbon cable could be used for connection. Here are some common sense hints when mounting the two

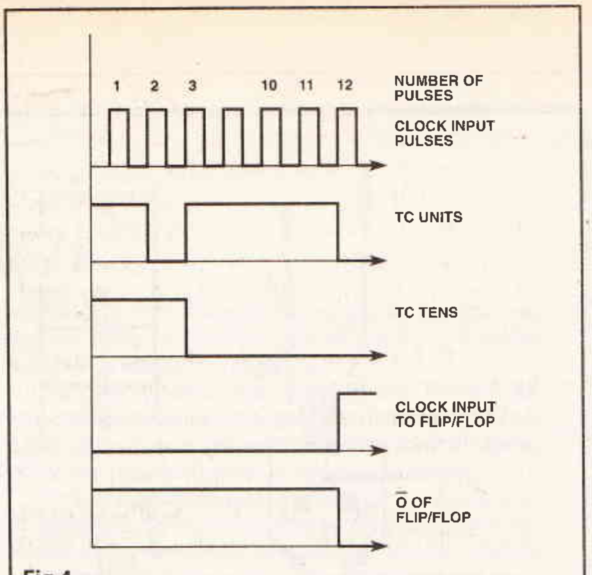


Fig.4

sensors. Don't forget to give the microphone access to the outside, so it can easily pick the sound it is meant to. Also it is advisable to connect both sensors to the board using screened wire. This is especially true of the infra-red sensor and equally so if a high impedance crystal microphone is used, as this reduces errors caused by pick-up. The same goes for the external input. Now, taking the usual precautions, the ICs can be plugged into their sockets. At this point the board should look like some plant life you find washed up on a beach with wires and bits everywhere.

Follow the same pattern with the second board taking a little extra care with the crystal. The connections for the seven segment display were again made easy for connection via ribbon cable, and for the prototype, I made a small PCB to mount the display on. But if you are a rich perfectionist then you can buy a purpose built holder and mounting bracket. A cheaper alternative is to use Veroboard.

When it came to boxing up the whole thing I used a

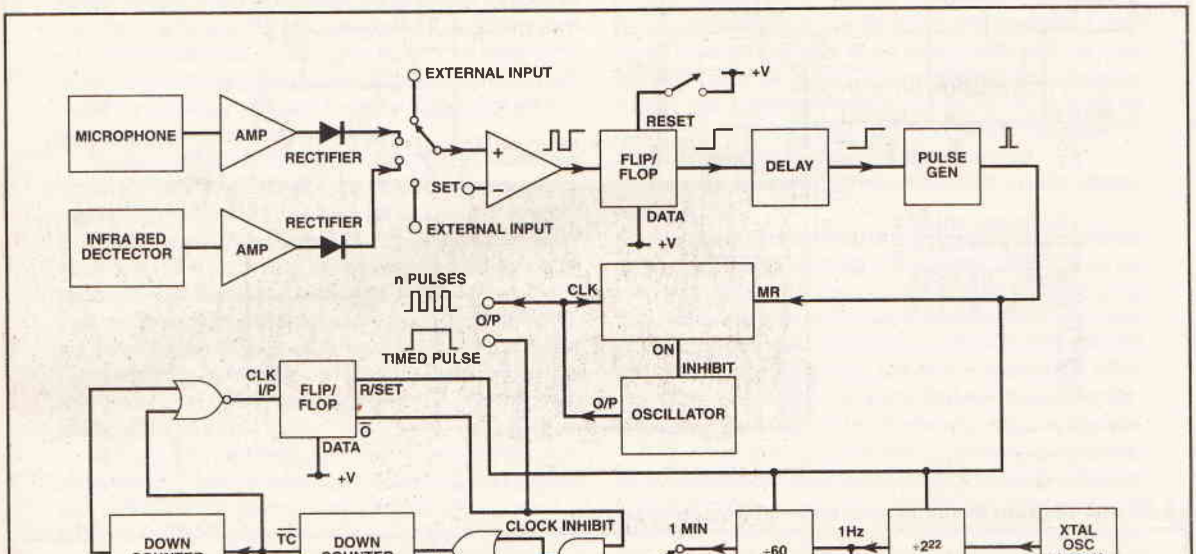


Fig.5 Block diagram

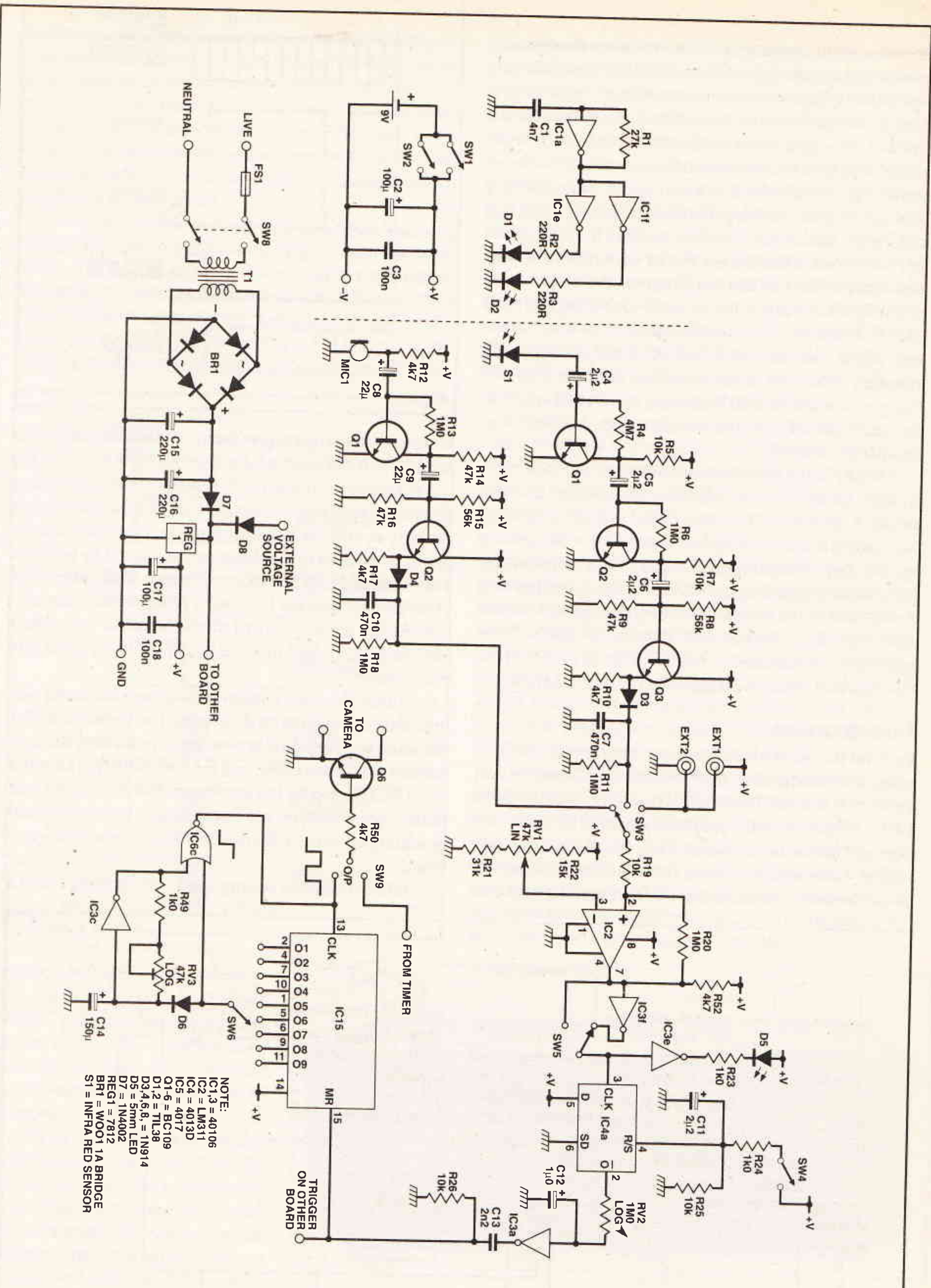


Fig.6 Circuit diagram of sound and infra-red detecting circuits

HOW IT WORKS

In this circuit the microphone used had a nominal resistance of 10k so a pull up resistor R12 of a similar value was used. If a noticeably different one is used, check that the resistances are matched by testing the voltage across the resistor lies in the 6 volt region. If you decide to use a crystal microphone or some other which actually generates its own voltage then remember to leave out the pull up resistor. Also the circuit may have to be altered a little, increasing the collector resistor R14 and placing an emitter resistor instead of tying it directly to ground. This may be necessary to increase the impedance of the input in line with that of the microphone.

Similarly if you feel it necessary to increase the gain on your infra-red link then feel free to increase the collector resistors R5 and R7 on both common emitter amplifiers. As it is, you are looking at a total gain well in the 3 figures region.

The hysteresis levels on the comparator are set to about 1/10 of a volt. The voltage divider chain has been set to a minimum threshold of around 4 volts and a maximum of around 9 volts. Again you can alter these if you wish by changing the values of the fixed resistors R21 and R22 at both ends of the chain. But as it is the minimum level (4 Volts) corresponds to the no signal bias points of both sound and optical rectifiers. Noticeably,this is the range within which any external analogue signals should lie.

The input to the flip/flop's clock is monitored by an LED (D5) which basically tells you when the comparator's triggering and is useful for setting the voltage divider. Do not be tempted to leave out the few resistors and capacitor which is associated with the reset switch, as these de-bounce the output of the switch and also make sure that the reset pin does not float when the switch is not pressed. The delay on the output provided by the potentiometer RV2 and capacitor C12 produces a delay ranging from 0 to 1 second with present components.

A simple mini circuit has been included that can generate an infra-red source. The single chip design uses yet another Schmitt trigger oscillator to generate a signal around 10kHz and this is buffered to drive two infra-red LEDs. While this is not a high powered circuit it is sufficient for use within reasonably short distances. A higher power circuit can be made using transistors to switch the LEDs on and off. Using this combination its possible to drive them with 100mA of current and achieve longer distance coverage. The power supply on this small board is a single PP3 9V battery, but the on/off toggle switch has been wired in parallel to a push switch which on pressing allows the unit to be used as a remote control.

On the multiple triggering part, the Schmitt trigger oscillator has been designed to give a range of frequencies from around 4Hz to 1 cycle every 8 seconds. There is no point increasing the maximum frequency as the automatic winders don't operate faster than around 5 or so frames per second. R49 controls the maximum frequency so if your camera's motor drive is faster or slower altering this value should bring it to line with your camera. The clock oscillator was designed so that immediately on triggering the clock line (also the output) goes high, thus the camera's shutter will open, the only delay being that set by RV2. This arrangement does cause the problem of the extended first pulse, but the error is not fixed and increases and decreases with the length of the other preceding pulses. Also the main purpose of this feature was to provide a fixed set of trigger pulses and not a high degree of accuracy between exposures.

The above circuitry was included on a single PCB with its own regulated supply. Provision has been made for a bridge rectifier with smoothing capacitors. This board runs best on a 12 volt supply and the other board on a 5 volt supply. The second board uses the same unregulated supply made on the first to drive a +5 volt regulator on the second. For portability a socket has been included to allow an external power source to drive it. A single diode has been included to separate the rectifier from the circuit, but even so it is best to unplug the mains supply if connecting batteries to the unit. The voltage of this supply should be at least around 15 volts. This is necessary to give the 12 volt regulator some headroom. Two PP3 9 volt batteries in series would do the trick.

Moving on to the timer board, the second time base generator seems self explanatory. The minute version needs a little extra circuitry to make it work. An AND gate IC9a provides us with a single divide by six output by ANDing O1 and O2, this is delayed by a RC combination and fed back to both counter reset pins. So after 60 pulses both counters are reset. The delay controls the length of the output pulse and so if it was not present the output pulse would be in the order of tens of nanoseconds (ie the propagation delays of CMOS gates). Please note that the trigger pulse from the comparator also is used to reset both the second counter and the two minute counters. This is necessary to ensure counting starts from the same point, otherwise huge irregular errors could occur especially when using small amounts of time. Also a diode is used to isolate the minute reset lines from the rest, without it, all others would be reset every 60 seconds because of the feedback from the AND gate.

The trigger from the comparator resets the output flip/flop (IC15a). When this occurs the inverted output goes high and gates, via an AND gate IC9d, the clock selected by SW8 (minutes or seconds). Only after triggering, will the clock pulses be allowed to get to the up/down counters.

The other source of clock pulses is the programming part of the circuit. To understand the workings of this it is best to look at Figure 3 and consider the three possible states. Firstly in the neutral state (switch not pressed) the input to the invertor IC16c with be low because of the presence of the forward biased diode connected to ground by the small value resistor R31. Therefore its output will be high and so forward bias the diode D11. This will raise the input of the next invertor IC16e high and so forces its output low. The proceeding invertor changes the state yet again so when the switch is not pressed the input to the AND gate is high on this input and low on the other. When the switch is first depressed the combination of R30-C24 acts as a debouncer, D10 becomes reversed biased and so is non conducting. C23 charges then through R32. It takes about 2 seconds for the voltage across C23 to reach +V/2 owing to the long time constant. So initially when the switch is pressed nothing happens along the series of invertors. The AND gate output is still high and as the other input is now high, the output of the gate will also be high. If the switch is released within the two seconds, all will return to the neutral state, and the result will be a single output pulse. If the switch is held for longer than two seconds C23 will be charged to a high level thus causing the output of invertor IC16c to go low. D11 is now reversed biased and sets off the Schmitt trigger oscillator built around IC16e. One of the AND gate's inputs will be high while the other will be oscillating and so its output will also oscillate. When the switch is turned off,diode D10 again becomes forward biased and quickly discharges C23 turning the oscillator off and things return to the neutral state.

Both this clock output and the other from the selected time base are ORed to provide a single clock input to the units up /down counter and this arrangement works fine once, as long as the timer is not programmed while it is in operation and is not a logical thing to do.

All the unused inputs to the up/down counters are tied low as well as the up/down line which means the counter only operates as a down counter. An OR gate and a single invertor is used to make a NOR gate which is connected to both the counters TC lines so when both these lines go low, ie the 00 state, it generates a pulse to clock the flip/flop, so forcing the inverted output of the flip/flop low. The output line is buffered by a spare OR gate and illuminates a LED to show the state of the output.

The seven segment display driver was set for use with common cathode displays.

The actual interface with the camera can take two forms. On electronic cameras cable releases are merely simple switches which short out two contacts and this fires the shutter, don't be deceived by a £30 price tag because that is all they are. In this case it is a simple matter of using an electronic switch, here I use a simple transistor switch (Q6) which works fine with my Nikon. Connection is made between the camera and the emitter and collector of the transistor, and so when the base is triggered the effective resistance between the emitter and collector falls triggering the shutter.

With manual cameras, the operation is a mechanical one requiring a pin to be pushed into the shutter button. This involves some form of electromechanical interface, the word solenoid immediately comes to mind. The same transistor could be used to operate the solenoid which would need to be connected to the end of the manual cable release. Remember to connect the push end and not the pull end of the solenoid. If you are going to use a high powered solenoid then also remember to either change the transistor from a low powered BC109 to something with a higher current handling to suit your needs, or use the BC109 to switch a relay which inturn would drive your solenoid. If you use the latter option, remember to include the reversed biased diode across the relay coil.

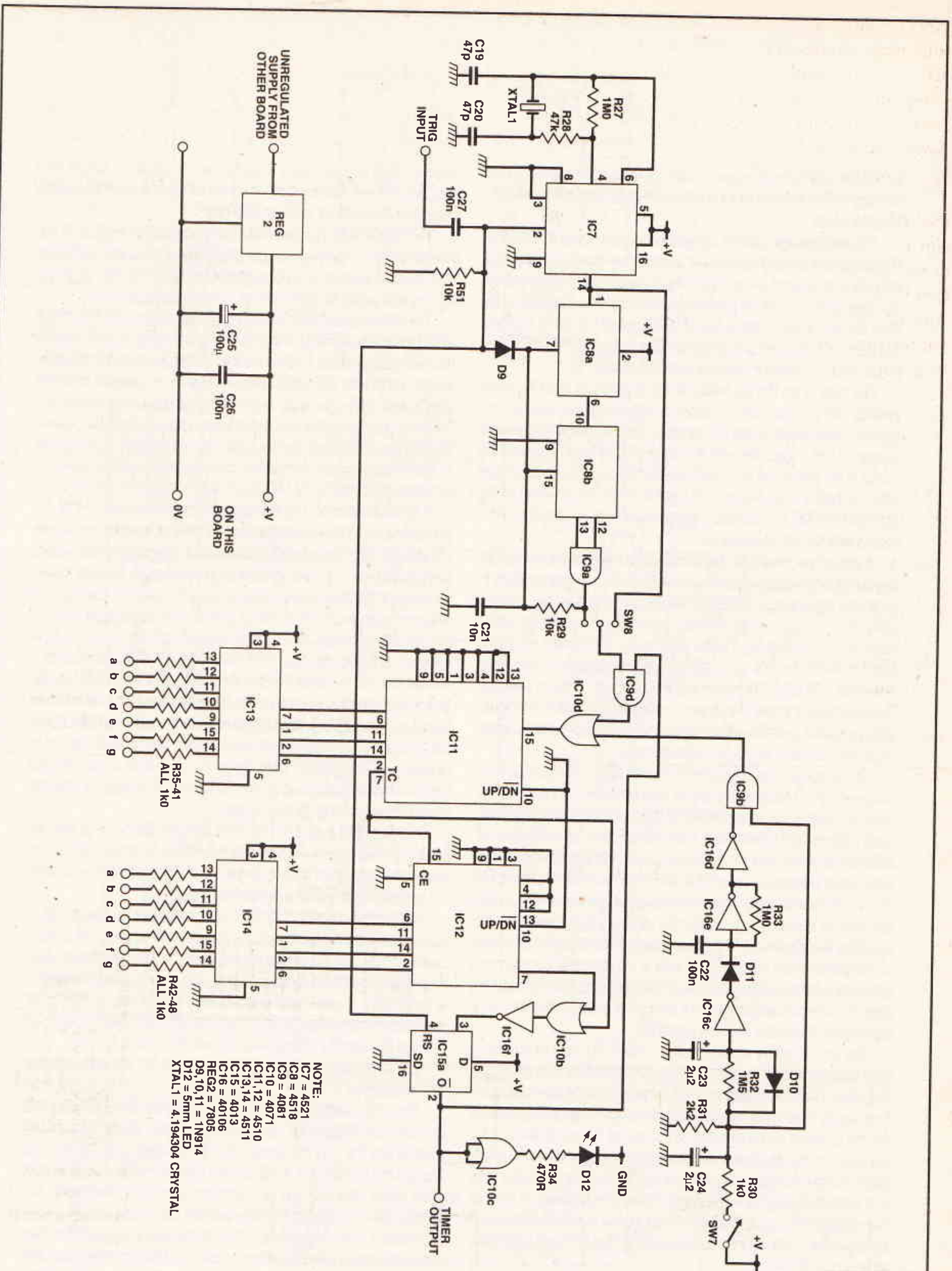


Fig.7 Circuit diagram for timing and display

sloping front case, not for any pragmatic reason but mainly because I had one lying around. For external connections I used phono connectors for the inputs and outputs. For the mains, a socket which accepted a detachable mains plug (as seen on most kettles) was used. This is a good idea if you want to use the unit out in the wilds without 2 metres of cable and plug trailing behind. The infrared emitter was housed in a small handheld box in the format of a remote control unit.

Testing

After connecting power to the boards check that the transistors Q3 and Q5 are both correctly biased at their bases (5.4 volts) and that the same is true of the output of the rectifiers (4 volts). Then, using an oscilloscope check the collector waveforms on Q4 while making a noise or playing an Iron Maiden album (roughly the same). There should be a representation of this noise here which should follow its level. Figure 1 shows roughly what to expect at different points in the circuit. If you've built up your infra-red emitter then you could check the collector of Q2 for some action when you point your source at the sensor and next to nothing when you don't. The output of the rectifiers can be checked using a voltmeter doing similar things as before (noise etc) and looking for a response from the needle.

You can check that the comparator is working using the LED D5. The easiest way is to set SW3 to sound input and RV1 to mid way and clap. The LED should flash every time you clap. If you flip SW5 to the inverted position then the LED should be normally on and extinguished when you clap. A quick look at the flip/flop's output (pin 2 on IC4) should confirm that all is well in the triggering part of the circuit. To check this press the reset button SW4 —it should go high. Clap again —this should force it low.

Next divert attention to the 4017 counter. Set the number of exposures to say 4 (ie set SW6 to position 4). Now monitor pin 13 while following the same procedure of pressing the reset button and clapping. If you get a series of 4 pulses whose frequency is varied by RV3 and a delay in the arrival of the first pulse dependant on the position of RV2, then you can turn to the next board. If not check the fine tracks around the connections to SW6 as a short across one of these could be ruining your day. Also glance at the polarity of the diode D6 as this is also a frequent problem when wiring circuits.

The second board is easy to debug. Start with the base signal, the 4.194304MHz one, use a 'scope to see if pin 4 on IC7 is oscillating very fast and if pin 14 is generating a 1Hz signal. Also check with a meter that pin 6 on IC8 is pulsing every 10 seconds and if you've got good eyes you may be able to spot a fine reset pulse on the reset lines (pin 7 and 15) once every minute, patience is needed. Again problems may be due to the polarity of a diode, here D9.

To check the programmer part of the circuit it is best to consult the 'How it Works' section. Press SW7 and the output of the AND gate IC9b should go high and again return low if you remove your finger quickly. Holding your finger down on the switch should cause the voltage across C23 to rise slowly and eventually cause the output of the AND gate to pulse at about 5Hz. Any problems blame the diodes. If its not their fault check your values of the resistors R30, R31 ,R32 as these values need to be relatively correct to ensure proper working.

All the messing around with the programmer should tell you if the counter/display combination is working. Any problem here should be easy to fix as you have a display to hand out free information on the state of the counters. If you ever see the counter going up, then the up/down line may be floating. If the counters are not synchronised, that is when the units display goes from 0 to 9 and the tens counter is not decremented, then look at the TC line on IC1 1 (pin 7) while pressing SW7 to act as a clock. There are three control lines on the display drivers which if in the wrong state may cause problems. Pin 4 on IC13 and 14 is the blanking input and if low, it blanks out the display. Pin 3 is the lamp test input, and if low, all

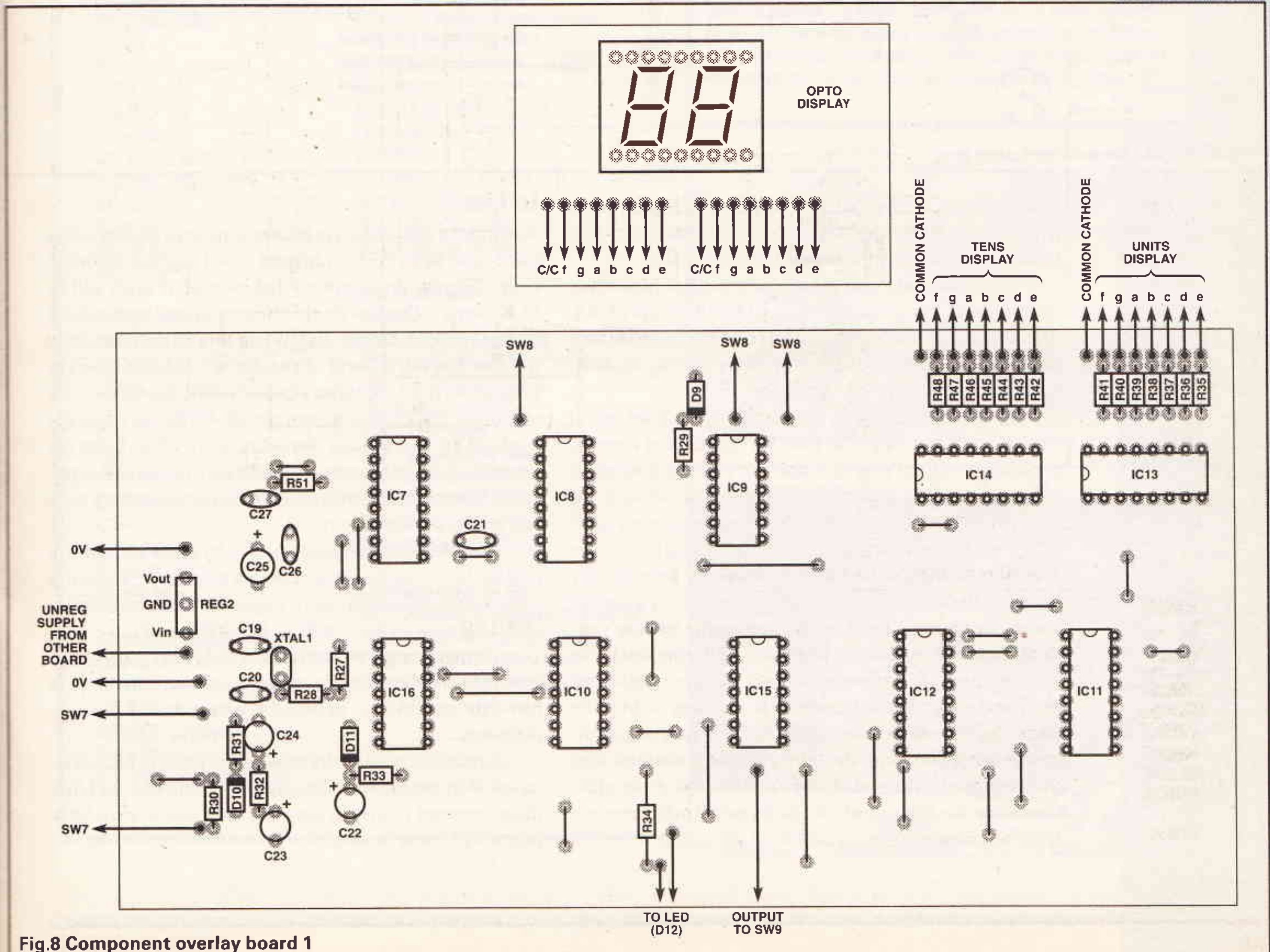


Fig.8 Component overlay board 1

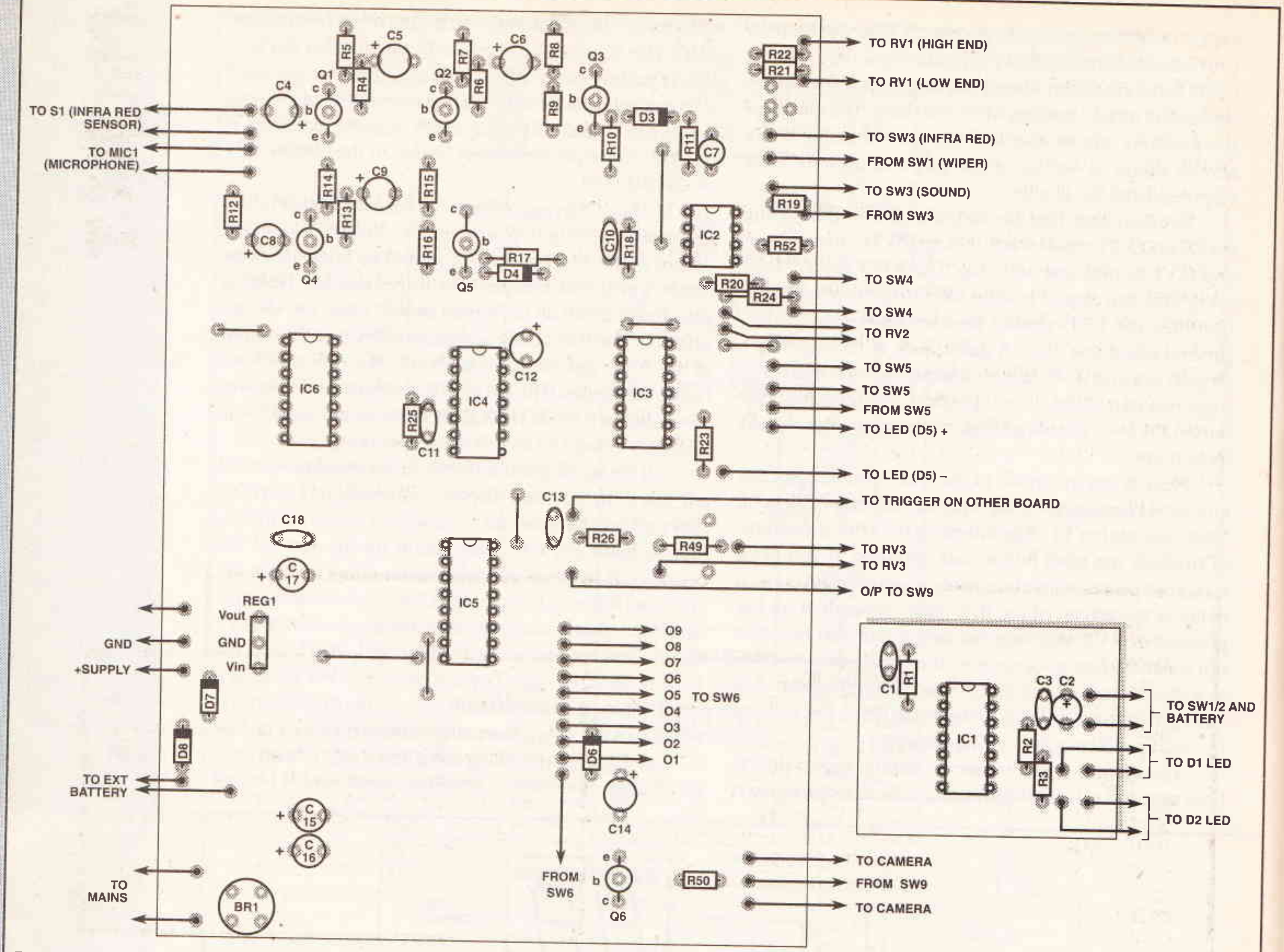


Fig.9 Component overlay board 2

segments light up displaying the number 8. Finally pin 5 is the latch enable and when high, the latch becomes transparent allowing the inputs to be decoded.

For a final test touch the trigger input line high while selecting seconds as a time base. LED D12 should illuminate and the display counts down from the programmed number of seconds. At the end when the display reads 00 the LED should turn off.

Now both boards can be married. For a final test of faith connect the output to your very expensive camera, preferably with no film in it and run through a range of exercises. Do this after reading the 'In Use' section. To test the timer, program in 30 seconds and turn your shutter selector to B setting, use the same clapping procedure as before to trigger the timer. You should hear shutter open for 30 seconds and then close. You can try a similar operation with the infra-red setting using, lets say your hand moving through the beam to trigger the timer. To test the multiple exposure setting, set the number of exposures to say 4, the frequency to mid way and try the clapping procedure. You should hear your camera shutter open and close and the motor advance 4 times. Any problems here will need a letter to your camera manufacturer to ask leading questions like 'How the hell does your cable release system work and what are its parameters?'

In Use

As this is an electronics magazine and not a photography one I have been fairly indulgent in writing this section. I have made the presumption that most of its users will be SLR owners. The first thing to be acquainted with is the B setting on your shutter dial. When this mode is selected the user has full control of the shutter, in basic terms as long as you hold the shutter button down, the shutter will stay open, the same is true of the cable release while the contacts are shorted, the shutter is open. While using the timer the camera must be in this mode to get timed exposures. When dealing with such long exposures there are a few points to remember;

Film does not respond linearly, by that I mean if you half the light you do not necessarily double the exposure time, you must add on extra exposure time to compensate. I have included a table to help (Figure 2).

Do not expect normal colour balance to appear in your prints as the different colour dyes react differently in low light conditions. Personally I have found blues to dominate.

Grain also tends to increase quite heavily. Do not be tempted to use higher speed films eg 1000ASA, as I find these respond poorly in very low light conditions. Stick with 100ASA or below.

A tripod or some other stable support is essential unless you like blurred photos

When using the multiple exposure setting remember not to use a frequency that is larger than maximum film advance speed of your winder or else your shutter will be triggered again before your film has wound on and you will lose an exposure. More importantly it is wise not to use this on the B setting as the timing of the pulses is not accurate. It is best to either use a manual setting if you know how much light is about or you are using a flash. Alternatively the automatic setting can be used to remove uncertainty. Remember, the exposure time must be faster than the time between trigger pulses or else you will be triggering the shutter while its still open.

Connection of the unit to your camera could pose some problems. The wealthy can always buy a cable release and cut off the switch and just use the wires for connection.

But this seems a bit of an expensive way of purchasing what amounts to a plug. I did try to get hold of just a plug from the Nikon Spares Department, but they didn't stock them, possibly because they might be bombarded with calls for them, from people who objected to paying £40 for a switch. But as they only make them its a case of like it or lump it. What I did was use two small spring clips from an old IC socket to grip the two prongs inside the socket. This worked fine but can be a fiddle when working in the field.

The setting up of the sensors is left to your creativity as it depends largely on what you want to photograph. With wildlife the optical sensor is particularly useful, and for sound events the microphone is useful. Do not forget to set the triggering levels to remove any background noise that might trigger your camera unwittingly, try some dry runs first. It is very important to make notes of delays times and exposure times used as a lot of fine tuning is needed to get good photographs. Most people do not have home developing facilities and so have to wait for some time to use up a roll of 36 exposure film and get the results from their experiments. The rest is down to good photography.

PARTS LIST

RESISTORS
R1=27k
R2,3=220R
R4=4M7
R5,7,19,25,26,29,51=10k
R6,11,13,18,20,27,33=1M
R8,15=56k
R9,14,16,28=47k
R10,12,17,50,52=4k7
R21=31k
R22=15k
R23,24,30=1k
R32=1M5
R34=470R
R35,36,37,38,39,40,41,
42,43,44,45,46,47,48,49=1k
R31=2k2
RV1 47k lin
RV2 1M log
RV3 47k log

CAPACITORS
C1=4n7 POLY
C2,17=100µ Elec
C3,18,22,26,27=100n Poly
C4,5,6,11,23,24=2µ2 Tant
C7,10=0.47µ Tant
C8,9=22µ Elec
C12=1µ Tant
C13=2n2 Poly
C14=150µ Elec
C15,16=220µ Elec
C19,20=47p Poly
C21=10n Poly

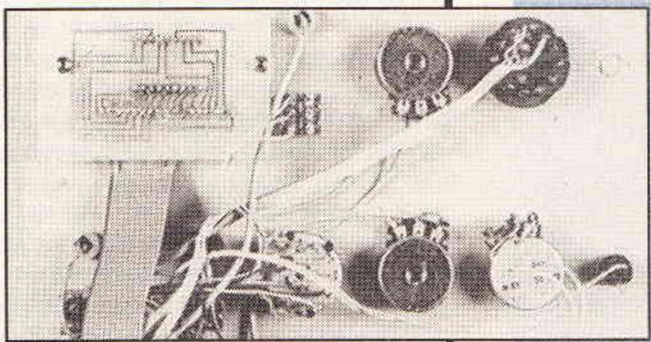
SEMICONDUCTORS
Q1-6=BC109
D1=TIL38
IC1=40106 Hex inverters
IC2=LM311 Comparator
IC3=40106 Hex inverters
IC4=4013 D type flip/flops
IC5=4017 Ten stage Johnson counter
IC6=4001 Quad NOR gates
IC7=4521 24 stage counter
IC8=4518 Dual bcd counter
IC9=4081 Quad AND gates
IC10=4071 Quad OR gate
IC11=4510 Up/Down counter
IC12=4510 Up/Down counter
IC13,14=4511 Bcd to 7 segment decoder
IC15=4013 D type flip/flops
IC16=40106 Hex inverters
D1,2=TIL38
D3,4,6,8,9,10= 1N914
D5,12=5mm LED
D7=1N1002
D11=1N914
BR1=W001 1A bridge
REG 1= 7812 +12V 1A Reg
REG 2= 7805 +5V 1A Reg

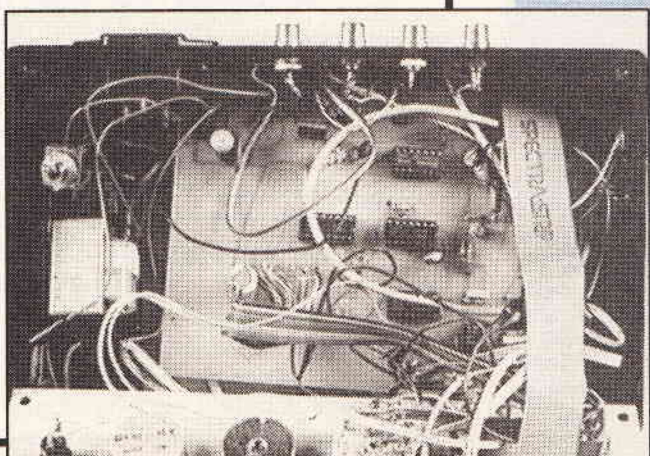
MISCELLANEOUS
Switches.
SW1 Sub miniture toggle SPST
SW2=Push to make SPST
SW3 = 1 to 3 way rotary switch
SW4=Push to make SPST
SW5=Miniture toggle SPDT
SW6=1 to 9 way rotary switch
SW7=Push to make SPST
SW8=Miniture toggle SPDT
SW9=Miniture toggle SPDT
SW10=Miniture toggle DPDT

S1 Infrared sensor (TL100)
MIC1 = Preferably low impedance carbon type
TRM 1 = 12 volt 6VA type transformer
XTAL1 = 4.194304 Mhz timing crystal
DISPLAY= Any 2 digit 7 segment display

Buylines

The infra-red LEDs used were high power types and the sensor was of the highly sensitive variety for obvious reasons. The microphone I used was from an old tape recorder but other types commonly sold can be used if the circuit is modified slightly. The crystal is of a common value and so should pose no problem. The display I used has the pin out shown on the PCB layout. All the other components are standard and available from most suppliers. If this project has inspired you to buy a camera so you too could use this project, try one of the photography magazines for information.





By John Linsley-Hood

One of the nice things about electronics is that all the components available to us continue to get better, which means that the performance we can get from our designs may also improve if we swap older device types for more modern ones. However, we may also need, from time to time, to revise our thinking about circuit types, in order to take advantage of the improvements which the device manufacturers have thought up.

A good example of this kind of progress is the way in which the 'noise figures' of semiconductors, ICs, and other components, have got better over the last ten years. The noise figure is a measure in dB, to which the shortcomings of the device we are using will spoil the theoretical performance of our circuit.

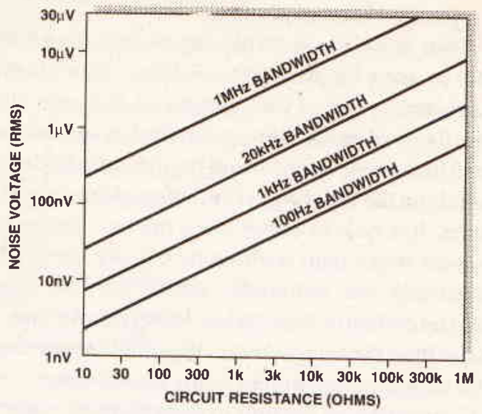


Fig.1 Thermal noise voltage vs bandwidth and circuit resistance

Low-Noise Systems

Are J-FETs now the best?

Although this improvement has been an all-round one, a particular effect of this has been to make junction field effect transistors, (which I will call J-FETs to distinguish them from MOSFETs —their 'insulated gate' cousins), usable in low-noise applications where one would, in the past have only considered using bipolar devices.

The basics of electrical noise.

Thermal noise

Before we look at possible design options, I think it might be helpful to take a brief look at the physics and mechanics noise, and then look at the ways these things relate to transistor construction and applications. The first of these (inescapable) noise sources is 'thermal' or 'Johnson' noise. This is generated by the random movement of electrons in any conductor, and whose RMS output voltage increases with temperature, resistance, and the bandwidth of the circuit in which it is used.

The well-known, and I hope familiar, formula for calculating this noise voltage is:

$$e(n) = \sqrt{4KT\Delta fR}$$

where 'e(n)' is the RMS noise voltage measured in volts/$\sqrt{Hz}$, 'K' is 'Boltzmann's constant' ($1.38 \times 10^{-23} \times JK^{-1}$), 'T' is the 'absolute' temperature, in degrees 'Kelvin'. (0°K = −273.15°C, so an average room temperature is about 298° Kelvin), 'ΔF' is the measurement bandwidth, and 'R' is the circuit resistance.

To put some sort of clothes on this formula, this means that the noise voltage which will be present between the two ends of a 1k resistor, just lying on your work bench and minding its own business, will be at least 0.29µV, when measured over a 30Hz to 20kHz bandwidth. As another example, a 1M0 resistor, measured at room temperature and with a 1MHz bandwidth, will generate, at the very least, 64µV of wide band noise.

(If you like, you can calculate the value of 'thermal' noise which will be generated by a range of resistance values, and with different measurement bandwidths, and if you plot it on log/log graph paper, it will give you a series of parallel straight line graphs, such as I have shown in Figure 1).

Similarly, a 10 Meg circuit resistance and a 10MHz passband will combine to give you 0.64mV of thermal noise. So if your mate tells you he has an electronic voltmeter with a 10MHz bandwidth, a 10 Megohm input impedance, and a maximum sensitivity of 1mV FSD, don't buy it from him unless it's very cheap.

I said, 'at the very least', because there are other noise sources as well, which will affect resistors, which I will look at in a moment.

'Shot' noise

Another source of noise which affects circuit design is 'shot' noise —so called because it is supposed to be like the effect of lead shot falling on a tin roof. This happens because electric current is always carried either by electrons or ions, and these are particulate by their nature, and the arrival of each one at its destination is a separate event.

This gives rise to a random current noise source which is, in this case, proportional to current flow, but not dependent on either circuit resistance or temperature, and is defined by the equation:

$$i(n)\ (rms) = \sqrt{2qI(DC)\,\Delta f}.$$

NOISE

where 'i(n)' is the noise current, measured in Amperes/$\sqrt{Hz}$, 'q' is the charge on the electron, (1.6×10^{-19} Coulombs) and 'I(dc)' is the circuit current flow, in Amperes.

Once again, to put some values to this formula, a 1mA current flow will be associated with 2.53nA of noise current, in a system with a 30Hz to 20kHz bandwidth. This will give rise to an additional 2.53µV of 'shot noise', in addition to the 0.29µV of 'thermal noise', if it flows through a 1k resistor.

Both thermal noise and 'shot' noise are unavoidable, and are what is termed 'white noise', that is to say noise which has a constant value per unit bandwidth, and would, in an audio system, sound like an uncoloured 'hiss'.

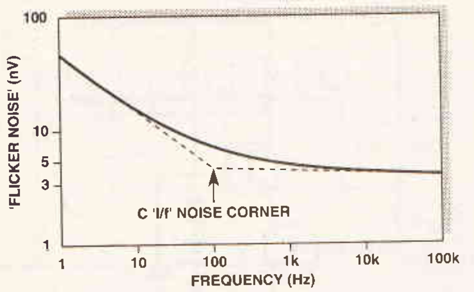


Fig.2 Typical 1/f noise curve for high quiality op-amp

'Flicker' or '1/F' or 'excess' noise

The third major noise source is what is usually termed 'flicker noise' or, more often, '1/f noise', because it gets worse as the frequency gets lower. This kind of noise, and others of the same type, is called 'pink noise', and, in an audio system, would sound more like the rustle of wind in tree leaves than the hiss of escaping steam which 'white noise' is said to resemble.

Unlike 'thermal noise' and 'shot noise' it is impossible to define '1/f noise' by any specific formula, because it arises as a result of microscopic structural defects in the materials from which the semiconductor devices or components are made, and is strongly influenced by the manufacturing process. Along with 'flicker noise' one can lump 'contact noise', which has a similar '1/f' noise energy distribution characteristic, and so cannot really be distinguished from it.

Although it is not possible to predict from scratch how badly a given device will suffer from 'flicker noise', if a large number of basically identical devices are tested, for noise, the average performance of these can be found, and generally has the characteristic shown by the equation:

$$e(f)\ (rms) \approx k\, I^{\alpha}/f^{\beta}$$

where 'e(f)' is the mean value of flicker noise, 'k' is some experimentally determined factor which is appropriate to the device being tested, and 'α' and 'β' have values which are about 2 and 1 respectively.

A typical flicker noise voltage graph, for a good low-noise op. amp., is shown in Figure 2. It is obvious that this kind of noise gets less important as the frequency is raised, and is almost non-existent above 1kHz. As I mentioned above, 'contact noise', (more properly described as 'bad contact' noise), has a very similar characteristic, and is due to the intermittent breakdown of partially insulating films of contamination between contacting surfaces.

'Flicker noise' and 'popcorn noise' —so called because it reminded the engineers who first noticed it, in audio systems, of the sound of corn being 'popped' by roasting is or was, a particular problem with FETs, and was observed to be worse if the chip surfaces were less clean than desired at the time of contact-pad metallisation. Improvements in manufacturing techniques have greatly reduced this kind of noise in J-FETs, though MOSFETs are still bad for '1/f' type noise, possibly due to the random creation and recombination of charge-pairs in the electrostatically generated conducting channel.

Excess noise in resistors

It is mostly the differences in the 'contact' and 'flicker' noise contributions, usually lumped together under the description 'excess' noise, which lead to the differences between say, the old carbon composition 'rod-type' resistors and carbon film, metal film, thick film, and wire-wound components. The difference also exists between those resistors with welded or soldered end connections, (better), and crimped cap end connections, (worse). As can be seen, the differences between carbon film and metal film types are not really very large, so if there are differences in sound-quality it isn't due to differences in the '1/f' noise.

Some average '1/f' type mean noise voltages for various resistor types are shown in Table 1. These are experimentally determined noise values for various 1k resistors, measured over a 30Hz-300Hz bandwidth, for a current flow of 1mA, expressed as µV per volt, and corrected for the 66nV due to thermal noise.

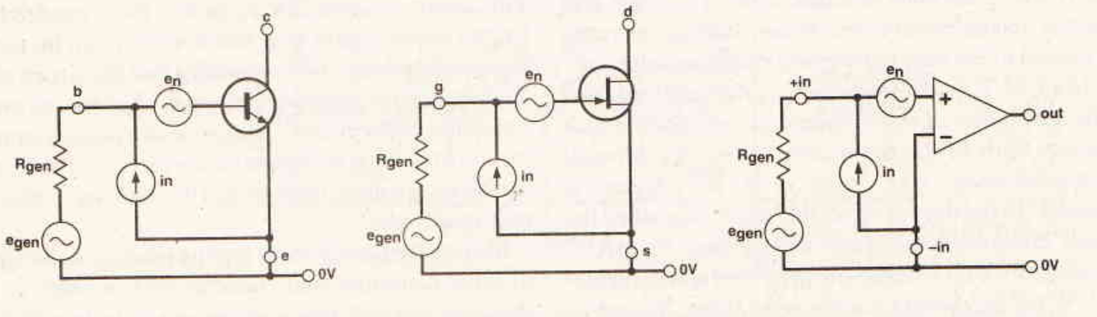


Fig.3 Device 'noise models'

Table 1.

Resistor type.	Flicker noise, (μV).
Carbon rod, crimped end caps.	0.2 – 5
Carbon rod, soldered end caps.	0.1 – 2
Carbon film.	0.05
Metal film.	0.04
Metal oxide.	0.03
Metal glaze.	0.02
Thick film.	0.02
Wirewound, crimped end caps.	0.03 – 0.1
Wirewound, welded end connections.	0.01 – 0.02

Transistor and IC noise

Noise models

It is conventional practice to consider noise in transistors and ICs as being due to specific noise sources connected to the inputs of an ideal noiseless amplifier. For convenience in visualising the way these input noise currents and voltages will affect a given circuit, their effect is simulated by one or other of the 'noise models' shown in Figure 3.

In these, the voltage noise source is considered to be a zero resistance noise generator in series with the input, (base or gate), electrode, and the current noise source is an infinitely high resistance noise generator in parallel with the input.

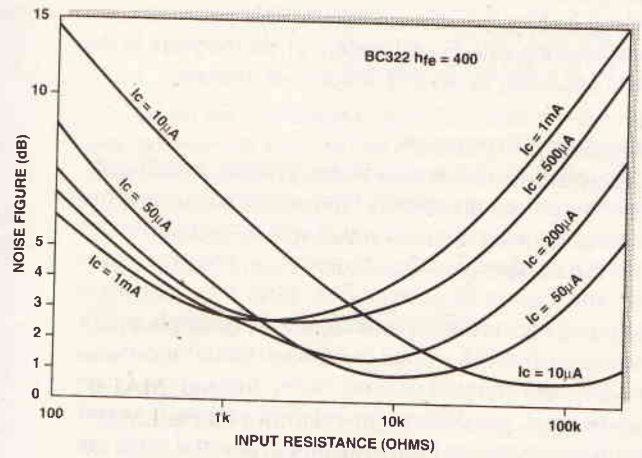


Fig.4 Transistor noise figure vs collector current and input resistance

In a junction transistor, the voltage noise source arises because of thermal noise in the 'base spreading resistance'—that distributed resistance between the base connection contact on the chip and the active base region of the transistor —and the bulk resistance of the base-emitter current path. The current noise is mainly 'shot' noise associated with the base current. However, to these noise components must be added some '1/f' noise, due to carrier recombination effects and leakage currents, and related to the base current and collector voltages.

In a J-FET, the thermal noise is principally that due to the resistance of the source-drain channel, which decreases both as the drain current and the 'forward transconductance' (the 'slope'), of the device is increased. [In the days of valves the 'slope' was called the 'mutual conductance', 'g(m)', and quoted in mA/V. Nowadays, for FETs, it is called 'g(fs)', and quoted in Siemens, 'S' or 'mS', but it's just the same thing.] So, unlike bipolars, the noise figure of J-FETs improves as the drain current is increased, within its working range.

Associated with this thermal noise voltage, in J-FETs, there are 'flicker' and 'contact noise' components due to impurities in the material. There is also an input noise current, which, at LF, is mainly composed of the gate leakage current, which is very small. MOSFETs suffer badly from '1/f' type noise, particularly if they have gate-protection zener diodes fabricated on the chip.

This generally rules them out for low-frequency, low-noise applications.

The same noise sources afflict ICs, which will either have junction transistors or FETs in their input stages. However, ICs also have an added 'shot noise' component due to the leakage currents through the multiplicity of

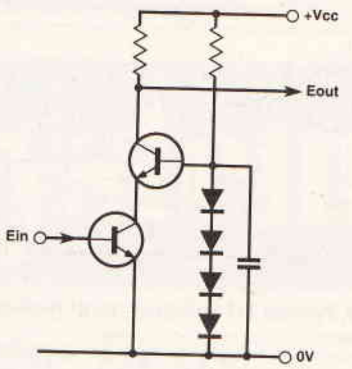


Fig.5 Cascode connection will reduce input device 'flicker' noise

reverse biased diode junctions which exist between all of the IC components and the P-doped IC substrate, (except the collectors of some of the PNP transistors, which may be connected directly to the substrate).

It is mainly the greater purity of the silicon substrate, and its dopants, which has reduced circuit-to-substrate leakage noise in modern ICs, and has allowed them to compete on more nearly equal terms with discrete component layouts.

Looking at the way the device input voltage noise occurs it is clear that very little can be done about this, since it will be added to any input signal, and any other input noise, such as the thermal noise due to the resistance of the Input circuit. On the other hand, the noise voltage produced by the device input current noise will depend on the impedance of the input circuit. The higher this is, the worse the noise. This is where J-FETs score, because of their very low current noise.

Low noise design

The circuit designer can do quite a bit to minimise the overall noise Figure of a low-noise circuit, by correct choice of devices, and by ensuring that the circuit resistance values are no greater than is needed for the proper operation of the circuit. In the case of a junction transistor, the first step is to choose the correct collector current for the known input resistance. If this is variable, choose a mid-range value.

Makers frequently show graphs relating 'noise figure' to input resistance and collector current, such as that shown in Figure 4. However, beware of the trap of thinking that a low 'noise figure' means a low noise. It doesn't. It just means that the transistor will not increase over any existing noise —due, perhaps, to the thermal noise in a high value input resistor —by quite as much as it would have done if the circuit had a lower input resistance.

A convenient formula for calculating the optimum collector current for an 'ideal' transistor is:

$$\text{Ic. (optimum)} = \frac{KT}{q} \times \frac{\sqrt{h(fe)}}{r(s)}$$

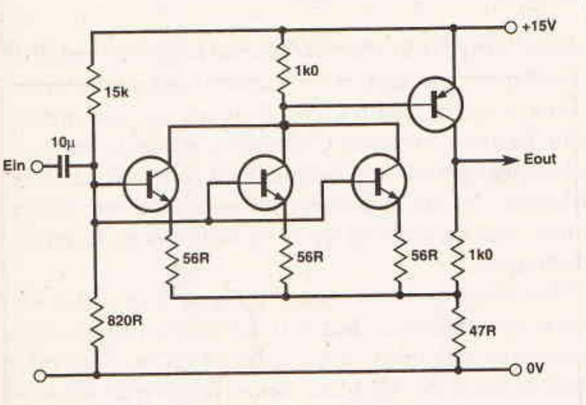


Fig.6 Parallel connection of input transistors will reduce thermal noise resistance

where 'K' is Boltzmann's constant, 'T' is the absolute temperature, 'q' is the charge on the electron, (1.6×10^{-19} Coulombs), 'h(fe)' is the 'common-emitter' current gain of the transistor, and 'r(s)' is the input circuit resistance.

Once again, putting some numbers to this equation, at normal room temperatures, 'KT/q' is 0.026, so, for a transistor with a current gain, 'h(fe)', of 400, and a source resistance of 1k ohms, the optimum collector current will be 0.52mA, a figure which is not too far away from that suggested in Figure 4.

Since the 'shot noise', and any 'flicker noise' accompanying the base current, will increase with the base current, it is a good idea to choose an input transistor with as high a current gain, 'h(fe)', as possible, because, for a given collector current, this will reduce the base current value.

Also, since 'flicker noise' and other '1/f' type noises, which are due to collector-base leakage currents, will increase with collector voltage, choose a collector voltage which is no higher than is needed to cope with the likely output signal voltage swing. Using a 'cascode' circuit layout, as shown in Figure 5, helps greatly in this respect.

Some years ago, it was taken for granted that a PNP transistor would have a lower 'flicker noise' figure than an NPN one, all other things being equal, since the 'N-type' base region in a PNP device would suffer less from carrier recombination and base region impurity (electron trapping) effects than a 'P-type' one. However, with modern devices, (e.g., transistors with BC numbers of 300 and upwards), the difference is really very small.

With very low source resistances, such as from a low output moving coil pick-up cartridge, or a strain gauge, the thermal noise due to the input base-spreading resistance of the transistor can be higher than that from the source. Paralleling a number of transistors can reduce the input resistance, but it will then probably be necessary to insert emitter lead resistors, as shown in Figure 6, to ensure that they share the collector current equally, and this will increase the transistor input resistance and its associated thermal noise.

An answer to this need, for a transistor with a very low effective input resistance, was provided by the 'National Semiconductors' LM194/394 devices. These are effectively matched-pair transistors made up, using IC techniques, from a large number of small devices, distributed across the chip to even out their performance, which are then parallel connected in two groups.

This results in an input base-spreading 'noise resistance' of about 40 ohms, and a 'bulk', (emitter circuit) resistance of about 0.4 ohms —but these devices are complicated to make and are therefore rather dear. Since then, 'PMI' have offered the 'MAT-01' and 'MAT-02' matched pairs, which slightly improve on the LM194/394 performance, and are cheaper to buy. Recently, they have also offered the 'SSM-2220' and 'SSM-2210'

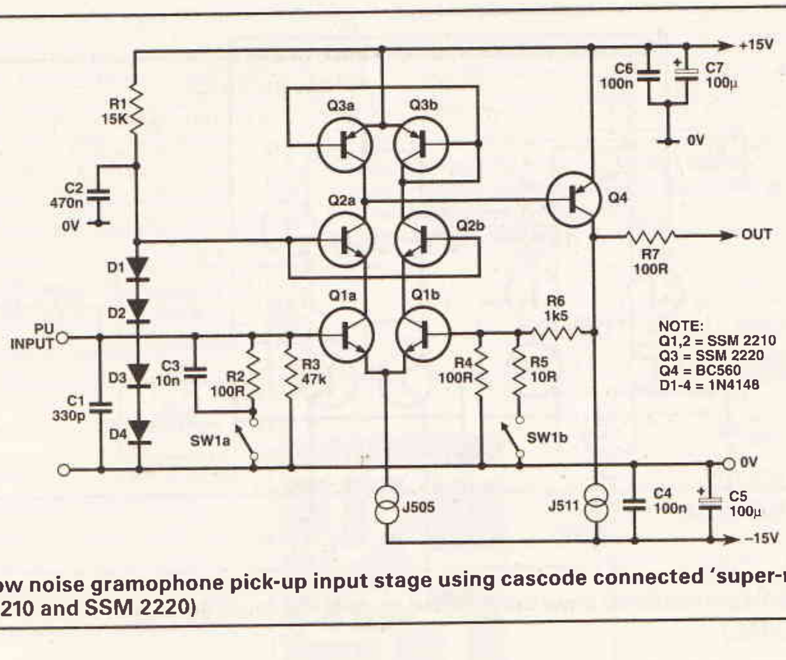


Fig.7 Ultra low noise gramophone pick-up input stage using cascode connected 'super-match pairs' (SSM 2210 and SSM 2220)

devices, which are respectively NPN and PNP dual matched transistor pairs, with a base-spreading resistance which is typically less than 30 ohms, and which are less expensive still.

A typical, ultra low noise, input stage for a moving-coil or moving magnet pick-up cartridge, using these devices, is shown in Figure 7. This is arranged as a flat frequency response gain stage with a switched gain choice of 1× or 150×, and an input impedance choice of 100R or 47k. For source impedances of less than about 100 ohms, bipolar transistors, of the 'super-match pair' type offer, at the moment, about the lowest noise figure.

However, device technology does not stand still, and J-FETs are rapidly catching up in performance.

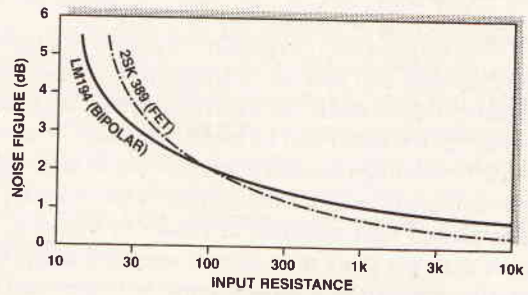


Fig.8 Relative noise characteristics of LM194 (bipolar) and 2SK389(FET) matched pair transistors

Low-noise J-FETs

Very low noise J-FETs have been available for upwards of ten years now, from firms like 'Siliconix' and 'Intersil', and, more usefully, are available in (dual packaged) matched pairs, for use in amplifier input stages.

This gets round one of the basic problems of J-FETs, that the drain-current vs. base voltage characteristics of the devices are influenced by so many factors, including doping level, channel geometry, and the crystalline uniformity of the chip, that both the cut-off voltage of the FET, and its drain current at zero gate-source voltage, (its 'I_{dss}'), are rather unpredictable, which would mean that some selection would be essential if one wished to find a reasonably well matched pair, using single J-FETs taken at random from a box.

The big problem with J-FETs, from the point of view of noise, has always been that the '1/f' type voltage noise contributions have been much bigger, and the thermal noise due to channel resistance has been a lot higher, than has been the case for bipolar devices.

The channel resistance of a J-FET is approximately related to the 'slope' of the Id/Vg curve as shown in the equation:

$$R(n) = 0.67/g(fs). \text{ (ohms)}.$$

where 'R(n)' is the effective 'thermal noise' resistance of the channel, and 'g(fs)' is the 'forward transconductance' —the 'slope' of the FET. The slope can be made higher, and the noise resistance made lower, by paralleling a lot of channels on the chip, in a similar manner to that of the LM194/394 multiple transistor array, and the 'flicker noise' can be reduced by more skilful manufacturing techniques.

The effect of this is shown in Figure 8, in which the noise performance of the LM194, (which is very good), is compared with that of a low noise J-FET matched pair, such as the 2SK389, which has a typical g(fs) value of 20mS, (20mA/V), and a consequent channel thermal noise resistance of 33 ohms. To this we must add the '1/f' noise of the device. Within the 30Hz-20kHz audio band it means that J-FET input stages are certainly usable down to input resistances of 100 ohms or so, and, above 1k a good J-FET will outperform, in noise figure as well as in linearity —even the best of the bipolars!

The penalty with low-noise J-FETs is that they have fairly large input (gate-source) and feedback (drain-gate) capacitances. This problem can be minimised by cascode connection, as for example, in the J-FET input stage design used by 'Spectral', shown in outline, in Figure 9, and which is usable down to moving coil pick-up input resistance values.

I have felt, for some time, that the future of linear amplifiers is with FETs of one kind or another. This time now draws nearer.

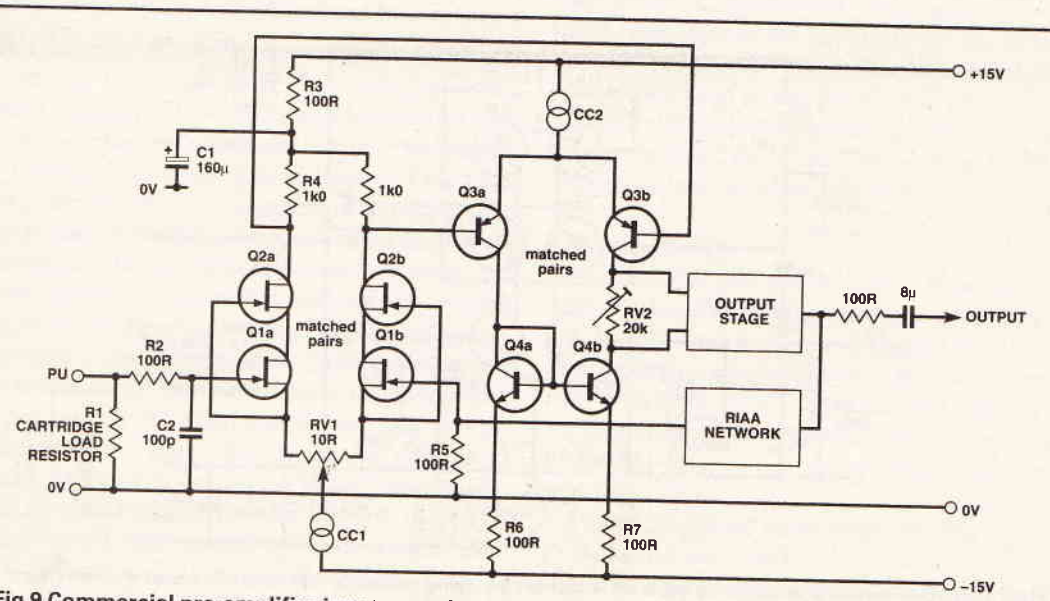
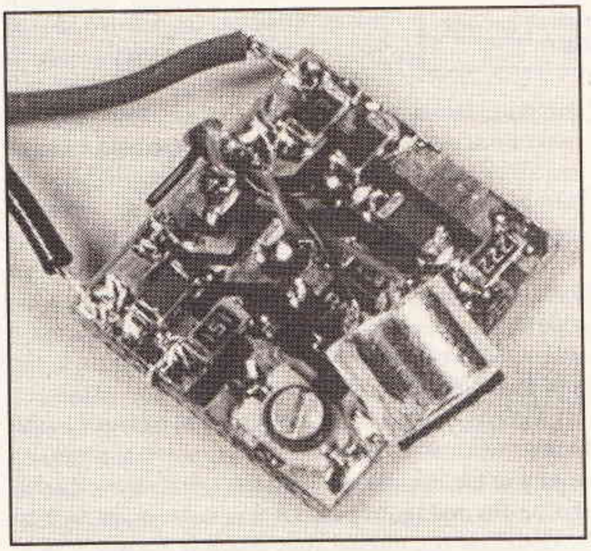


Fig.9 Commercial pre-amplifier input stage based on dual FET input devices

A Mini Baby Bug

This Tiny 'Bug' transmitter produces an excellent quality wide band FM signal received on any VHF FM radio receiver. It is ideal for use as a baby monitor. Presented by Bill Mooney.

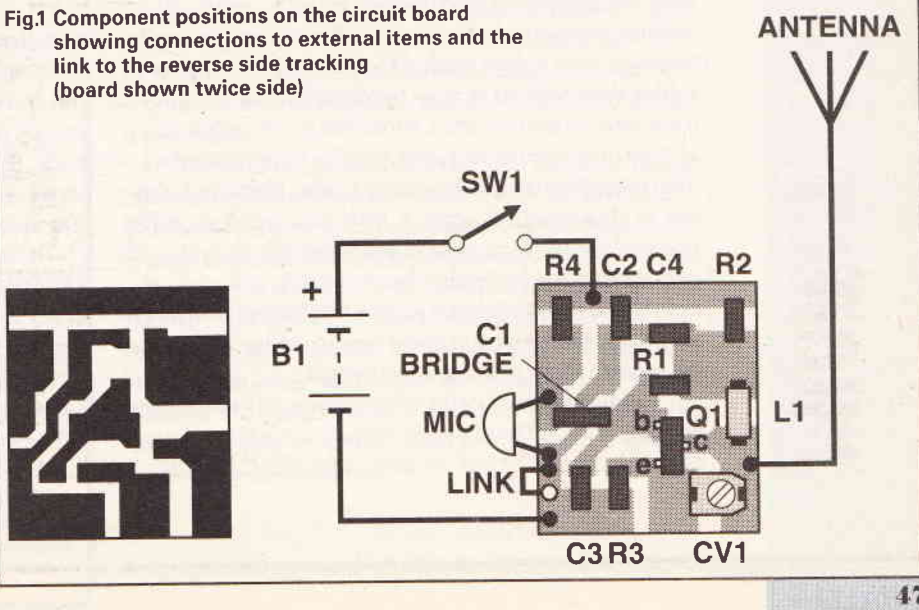


This little microphone transmitter will produce a fully quieting FM signal throughout the average household and probably into the garden. Performance depends on the sensitivity of the FM radio receiver used for monitoring but most portables have been found to work well. The elegance of the design lays in the use of a very simple reflex circuit with only one transistor. Implementation of this with tiny Surface Mount Devices (SMD's) and a minimal component count results in a very compact circuit. Under normal conditions the FM receiver will be fully limited and therefore remains totally silent until a sound is made in the room being monitored. This obviates the need for sound activated switching. You will be amazed with the powerful clear FM quality from such a small device.

Construction

The circuit is fabricated on a small double sided PCB measuring 1.70cm by 1.45cm. A double sided PCB is preferred for this type of construction. It has a much lower tendency to warp and therefore reduces the strain on the chip components. The 1206 size chip components are recommended. This is a good size for ease of hand soldering and yet allows us to produce a very compact circuit board compared to fabrication with leaded devices. With all chips aboard, the profile is only a few millimetres. Whilst you may

Fig.1 Component positions on the circuit board showing connections to external items and the link to the reverse side tracking (board shown twice side)



design your own printed circuit board, the layout shown in Figure 1 is well tried and tested.

To put the circuit together you will need, at least, a pair of tweezers, a 12 Watt soldering iron with a fine tip and some fine rosin cored LMP solder. LMP or Low Melting Point solder has a little silver metal added to the alloy in order to reduce the melting point to about 180°C. This puts less thermal stress on the chip components. If you have not used SMD's previously then start with, say, R4 which is out in the clear. But first a slight digression.

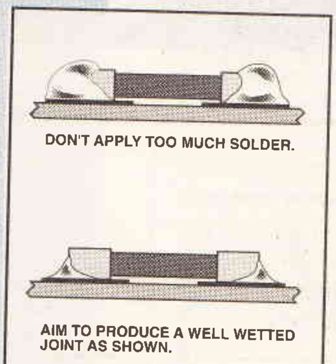


Fig.2 Application of correct amount of solder

It will soon become obvious that you need to pin down the little blighter in order to solder it in place. In commercial construction the chips are placed on a couple of dabs of solder cream which is tacky enough to hold it in place. Sometimes a spot of glue may be used as well. The whole circuit board is then heated up by infra-red or other means to the point where the cream reflows. The process whereby the grey coloured solder cream decomposes and the bright solder appears is referred to as 'reflow'. With this technique both ends of the chip are therefore soldered in place at the same time. For hand working you never need to use glue but you could use solder cream and a little gas powered hot air blower to reflow it. For the purposes of this article we will assume that you are using the trusty old soldering iron. So back now to R4.

You will have enough problems pinning down wayward chip components let alone a moving PCB, so fix the little board to the bench with a blob of blu-tack. Place R4 on its pads with a pair of non magnetic tweezers. If you now try to solder one end of the chip it will stand upright. This effect is known as tombstoning and is caused by the surface tension of the solder. The solution is simply to hold the chip down with a wooden toothpick whilst soldering one end to the pad. The second end can then be soldered on the normal way. Another approach is to obtain an SMD Assembly Jig specifically designed to hold chips in nice alignment for soldering. The advantage of this device is that it will allow the application of solder and iron tip to the device simultaneously, the best way to make the most reliable joints.

Whatever method is used it is good practice to minimise the amount of solder used, piling on more solder will not give you a better contact. Excess solder can be removed with solder wick. One reason for using more solder than needed is poor solderability of the circuit tracking or of the chip ends. More and more solder wire is pushed into the joint as a source of flux for improved wetting rather than the need for more solder. If you find yourself in this situation apply a little flux paste or spray. Figure 2 shows what a good soldering job should look like. We aim for perfection but it is rarely achieved and even if your finished circuit looks a bit shabby it will probably work. Now that you know how to solder SMD's lets get on with the rest of the construction.

Solder in the rest of the resistors now followed by the chip capacitors. The capacitors have no markings so take care with them. The 1µF ceramic capacitor C1 bridges a track so place this with great care squarely on its pads. The transistor Q1 is a bit crowded by the trim cap and the inductor and should therefore be soldered in before these devices. A CTZ type trimcap is preferred for TC1. These are ultra thin ceramic devices and have excellent stability and freedom from backlash in this circuit. This type of trimmer and the use of a fixed inductor makes it a simple matter to adjust the oscillator to the required frequency. The reverse side of the PCB should be connected to the 0V tracking on the component side using a loop of stripped Kynar wire snugly wrapped around the edge. Finally, a light spraying of solder-through protective lacquer will protect the little 'chappies' from the harsh world.

Boxing It Up

A small circuit like this can be built into a toy or some other object or you may go for an ultra small approach. Here we describe a very practical approach which doesn't need an engineering workshop to complete. It is built into a small plastic mountable box type B1A measuring 50mm × 37mm × 24mm. It's all very well having a battery screwed up inside your project box but after a few changes of battery the average self tapper will be about as much use as a chocolate teapot. It also assumes that you have a miniature screwdriver handy. The bug runs on a PP3 battery and for economic reasons a Ni-Cad rechargable is recommended. This will need to be swopped frequently for a charged one. The construction of the bug is shown in Figure 3. The battery slots neatly into the side of the box and with this arrangement it can be changed in seconds.

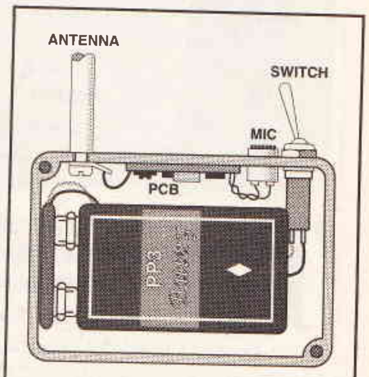


Fig.3 Internal construction of the baby bug showing the placement of the PCB and other items

The plastic is easily worked and slots can easily be cut in the side of this box to take the PP3, as indicated. Holes need to be drilled to take the switch, microphone, and aerial. The electret microphone is held in place with a little quick setting Bostic adhesive. Similarly the circuit board is glued to the side of the box. Thin Kynar wire is then used to connect up the microphone and aerial. The leads from the battery clip conveniently run through the mounting holes in the rear of the box to the switch and circuit board ground track. A tag washer can be used for connection to the aerial. An small telescope aerial extendible to about 30cm is needed.

Testing 1, 2, 3 . . .

Apply power to the circuit from a Ni-Cad PP3 battery. The first task is to determine how much current is being drawn as an indication that there are no major problems. A current of 2.7mA will produce a voltage on the cold end of L1, where it joins R2, of 3.4V, with respect to ground. Check that the voltage on the microphone is a volt or so below the supply rail. Finally check the voltage on R3, it should be about 0.4V. If these tests are passed the circuit is probably working as it should.

To set it on frequency an FM receiver is required, preferably a portable device. Set the receiver to say 104MHz and place it several meters away with the volume set to a position where the inter-station hiss is audible. The bug oscillator is free running and is very prone to hand capacity effects therefore keep the aerial well away from metallic objects and use an insulated trimtool. Slowly rotate TC1 and at some point the receiver hiss should disappear as the bug signal comes on frequency. If you can't find the signal try tuning around on the receiver or altering the aerial length. The signal strength should be sufficient to limit in the receiver giving a totally quiet background except for audio picked up by the microphone. You may get some feedback which is a good indication. Many FM receivers will pick up more than one response over the tuning range of TC1. Keeping the transmitter and receiver well separated whilst setting up will help sort out the correct signal.

If you now take a walk with the portable receiver you should find a good signal around the house with perhaps a couple of blind spots due to wiring and so on. It will be easier to make all fine adjustments using the receiver tuning when setting up. The transmitter is deliberately under modulated as an over sensitive device will be very effective at relaying traffic noise and other spurious sounds. However, the odd background noise is reassuring that the communication channel is functioning correctly. The audio can be reduced by lowering the value of R4, just put another resistor on top, piggyback fashion.

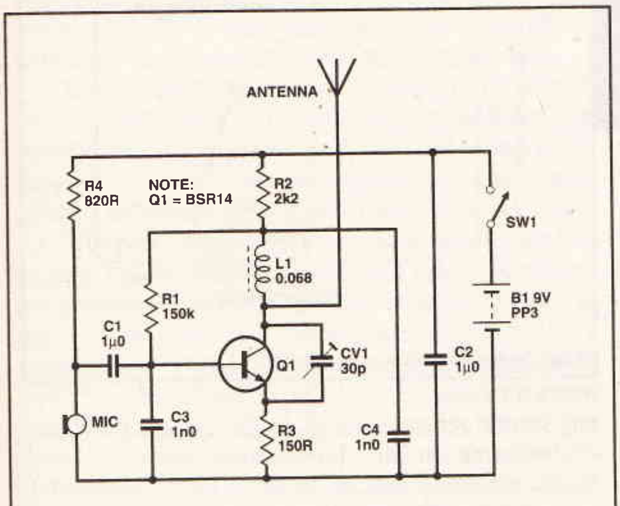


Fig.4 Schematic diagram of the mini FM transmitter

HOW IT WORKS

The schematic diagram of the transmitter is shown in Figure 3. This makes use of the old "reflex" technique dating from the time when active devices were expensive and were sometimes made to perform two functions at the same time. In this case the transistor Q1 is acting as an audio amplifier for the signal from the electret microphone. The amplified signal appears at the collector, R2 being the collector load resistor. R1 provides bias and D.C. feedback to set the collector to about 3.4V producing a simple grounded emitter amplifier. At the same time the transistor is operating as a grounded base oscillator at VHF, the base being grounded to RF by C3. RF feedback to the emitter through TC1 sustains oscillation. The frequency is determined by L1, TC1, stray capacity and the collector base capacity of Q1. Now the collector base junction is reverse biased and looks like a variable capacitance diode. Since the amplified audio appears across this diode its capacity, and hence the VHF frequency, will swing in sympathy with the audio input. Output is taken direct from the collector using a short aerial. The frequency of oscillation is set with TC1. The RF power INPUT to the transistor only, is about 8mW from a total power to the bug of about 25mW.

PARTS LIST

RESISTORS

R1	150k	1206	2% chip resistor
R2	2k2	1206	2% Chip resistor
R3	150R	1206	2% chip resistor
R4	820R	1206	2% chip resistor

CAPACITORS

C1	1μ	1206	Y5V dielectric chip cap
C2	1μ	1206	Y5V dielectric chip cap
C3, C4	1n	1206	COG dielectric chip cap
TC1	30p	Type CTZ trim cap	

SEMICONDUCTORS

Q1	BSR14	SOT23	NPN transistor Inductor
L1	0.068μH	1210	Chip inductor Type TDK NL322522

MISCELLANEOUS

Miniature electret microphone type ECM10A.
Miniature on/off switch
PP3 battery clip
Small mountable box.
type B1A. 50mm × 37mm × 24mm

The frequency will shift due to temperature, proximity to other objects and battery voltage. Consequently it is best to set up the bug in a quiet spot and make final receiver adjustments as required. In practice it will run for many hours without attention but it should only be switched on when needed to conserve battery life. A battery supply should be used, ideally a pair of rechargables which can be alternated and more important have a relatively constant voltage. Don't try to use a mains supply as the slightest ripple will produce unacceptably high levels of hum and noise. The frequency stability of the prototype is shown in Figure 5. It will be seen that after an initial drift over a couple of hours the frequency remained steady and no further adjustment to the receiver was needed for 33 hours when the battery voltage began to drop. The AFC was good enough on the test receiver, a Sony ICF-450L portable, to warrant only one slight re-tune at the initial period and kept the frequency locked on thereafter. I measured a change of frequency of 400kHz per volt. Over a 30 hour test period after the initial voltage drop the battery voltage dropped by an another 0.44V only corresponding to 174kHz. With a normal receiver bandwidth of 200kHz and a reasonable AFC you should have to make only a very occasional re-tweek of the tuner. With 8 hours of monitoring each day the battery should last some 4 days.

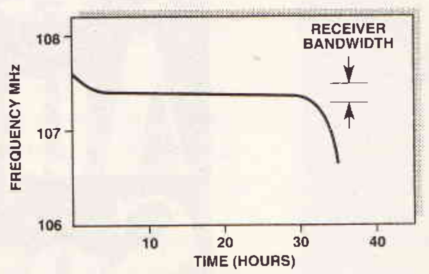


Fig.5 Frequency stability with a Ni-Cd PP3 size battery. After an initial drift, the receiver will not usually need further adjustment

It should be pointed out that it is illegal to use an unlicensed transmitter and further it is not possible to obtain a licence for this frequency in the UK. If this device is used as recommended it will radiate less power than the average computer or the local oscillator in an FM receiver. It is good practice to restrict the aerial size to that which will achieve the required performance. A small 30cm whip which can be retracted is therefore advised. Any attempt to use this device beyond the bounds of your property would contravene the spirit of the present deregulation.

Ultrasonic Audio Sender

Send your TV audio by wireless ultrasonics. Presented by Peter Cartwright

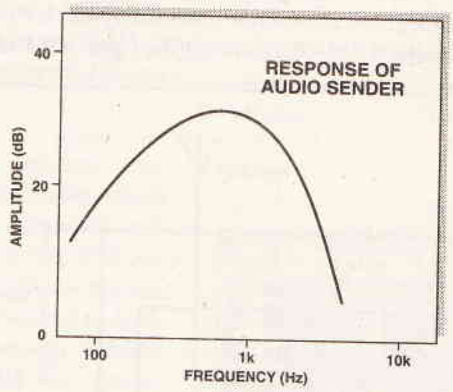


Fig.1 Response of audio sender

Audio wireless senders have been commonly available for a long time. Usually employing infra-red as the carrier. Their main advantage over conventional headphones being to lend greater mobility to the user. It came about that just such a system was required for listening to late night television.

There are three practical ways to create a wireless link. They are Infra-red, radio and Ultra-sonic. As far as fidelity is concerned, infra-red will have the advantage, but considerable power is necessary to give a useful range. Whilst radio has interference and licensing problems associated with it, and if hi-fi isn't a must, ultrasonics are worth considering especially for the above use where speech is of principal interest. In fact as Figure 1 shows even music can be enjoyed by this means. For a given unpulsed power output, an ultrasonic link will have a much greater range than its infra-red equivalent. The design described in this article provides sufficient range for the home environment. Both transmitter and receiver consume only a frugal 10mA, making the use of a small battery feasible. A 500mAh alkaline PP3 is recommended.

The Transmitter

This employs the LM13700N integrated circuit, which is a dual transconductance amplifier. This means, its output current is proportional to the voltage difference across the inputs. The ratio or transconductance is controlled via pins 1 and 16. In fact a linear relationship exists between the current entering these pins and the value of the transconductance.

In our transmitter, amplitude of the carrier has to be modulated. This can be easily accomplished with the transconductance control pin. Another useful feature of the LM13700N is that it can produce an approximate triangular wave using a single amp. Thus one amplifier can be configured to generate the carrier and the other to modulate it.

Oscillator IC1b has as its output from pin 10 a constant current fixed by the voltage across pins 13 and 14. Therefore at some arbitrary time the voltage over C4 will increase or decrease in a linear fashion, producing the voltage on the diodes of 0.6 volts. As the diagram shows pin 10 is buffered by the Darlington transistor which

PROJECT

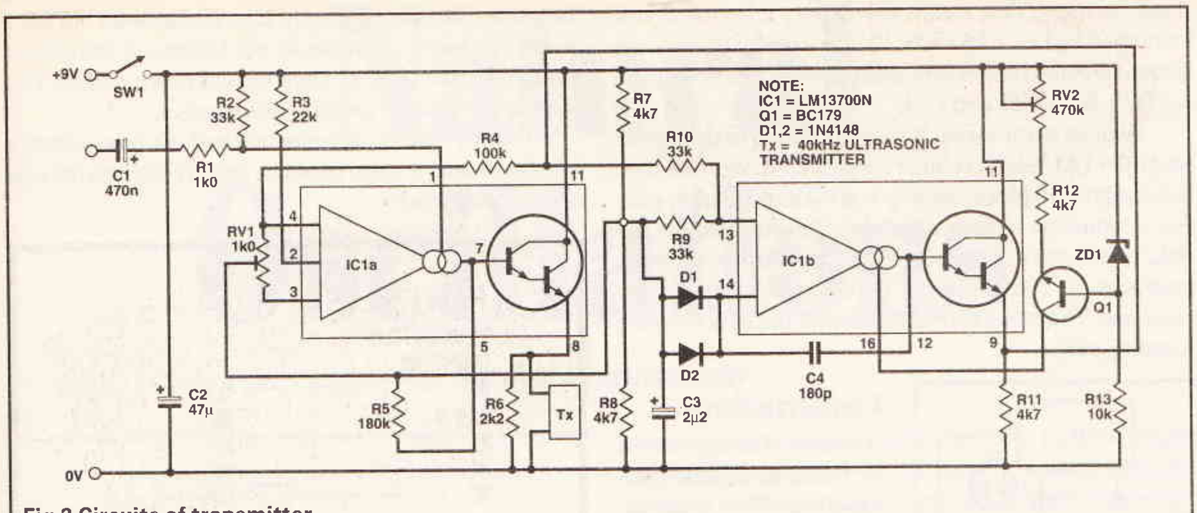


Fig.2 Circuits of transmitter

drives the voltage divider R9, R10. Thus if the voltage relative to earth (pin 9) is twice that of the diodes, current from the output will switch its direction, completing the other half of the cycle.

As previously said, the triangular wave is not perfectly shaped and the reason can now be seen. At the switchover point, an abrupt change of 1.2 volts will occur across the diodes. This must appear on the waveform.

The frequency of the oscillator must be stable, which requires a steady current to enter pin 16 irrespective of the supply voltage. Constant currents are conventionally achieved by dropping a controlled voltage across the emitter resistor of a transistor. A PNP type transistor was chosen because the voltage must be referenced to the positive rail. The emitter voltage will come to rest about 0.6V above the base giving the base voltage stability.

Unfortunately the voltage of cheap zener diodes varies considerabley with current and temperature. The introduction of one resulted in a 9kHz error as the supply dropped from 9 to 6 volts, hence the need for a reference diode. The voltage drop is now fixed across RV2 and R12. The preset alters the current and the oscillators frequency. The device can be operated from a regulated power source,if required. The above transistor can be replaced by a wire link connecting R12 to pin 16. If required, the value of the resistance can be calculated from this. The voltage on pin 16 is 1.2V and the current should be 135µA approximately.

To prevent the waveform being clipped as the supply voltage descends to 6V, its peak to peak value being kept to 2.4V.

Taking the modulator amplifier, we can see the transconductance biased by R2. R1 and C1 have their value chosen to increase the treble response of the circuit.

The Receiver

The device is designed for a domestic setting. So an operating range from two to fifteen feet was chosen. Moreover, the option of battery operation was considered desirable.

Functionally, the circuit is composed of six parts. A high gain preamp is followed by high and low pass filters. The detector stage leads to another low pass filter and finally on to a small power amplifier, which is sufficient to run headphones. The preamp centred on Q2 gives a 35dB gain in voltage. Its output is fed to the high pass filter around Q3. 40kHz ultrasonic transducers are insensitive to audible frequencies, nevertheless, the detector will pick up low ultrasonic noises from clothing being rubbed. A high pass filter is therefore essential. This is a 24dB per octave type. The low pass filter network created from R22, R23, C10 and C11 reduces that other enviromental nuisance, radio transmissions. Q4 is another buffer amplifier like Q3 and its output feeds the

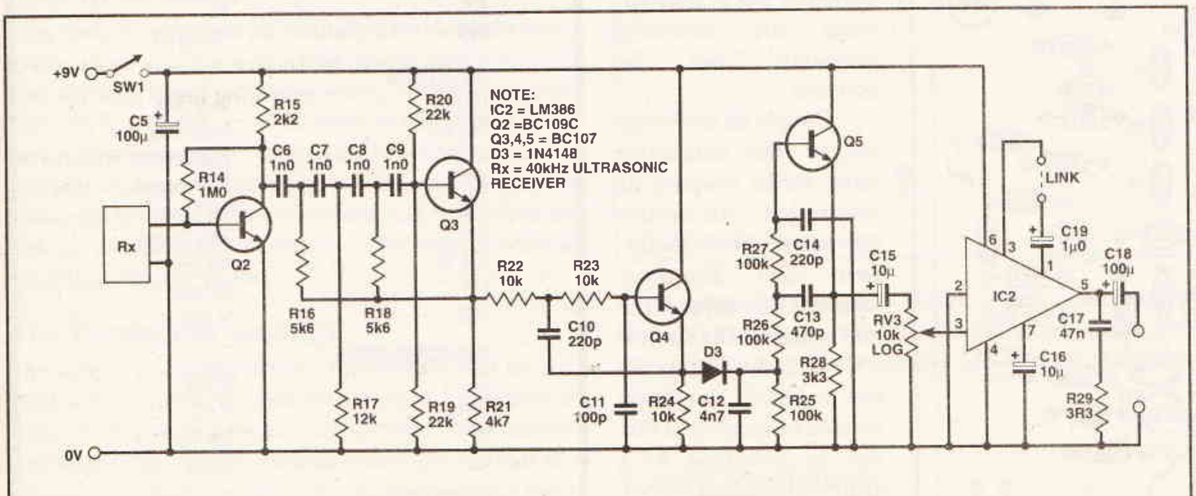


Fig.3 Circuit of receiver

detector stage. This means the carrier is rectified and smoothed by D3, R25 and C12. Any residual ultrasonic frequencies are further diminished by the filter comprising R26, R27, C13 and C14.

A clean audio signal is thus presented to the power amplifier LM386 via volume control RV3. With the wire link soldered in place, the amp is set at its maximum gain. For a reduction in gain, a resistor is substituted for the link. 1k will give slightly over 40dB, whilst an open circuit produces a 20dB gain. C19 affects the frequency response. The value shown attenuates the bass to make listening easier.

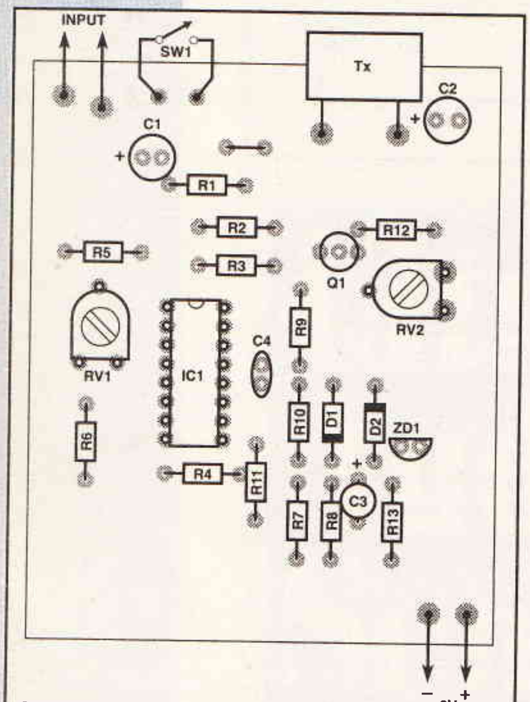


Fig.4 Component overlay for transmitter

Construction

A couple of things should be noted as regards construction. The transducers are soldered to 1mm PCB pins which protrude from the board. Switch 1 and 2 will fit the front panel using the case recommended. Solder a 3.5mm jack socket to the input wires. This is better fitted to the top of the enclosure. To prevent picking up mains hum, the cable connecting the signal source to the transmitter should be screened. Finally the stereo socket must be wired to run your headphones in parallel, otherwise the sound will be out of phase.

Setting Up

Firstly the receiver's volume control should be adjusted so that a slight hiss is heard through the headphones. Now switch on the transmitter which should be a few feet distant. To adjust the frequency to 40kHz, you could use an oscilloscope or frequency meter connected to pin 9. Alternatively the following procedure can be adopted.

Couple an audio signal to the modulator input whilst keeping its volume low. This ensures the carrier isn't modulated into distortion. Rotate RV1's wiper to the mid position. Then adjust RV2 until the best sound can be heard. You might be able to improve it further by twiddling RV1 again. Incidentally RV1 controls the symmetry of the carrier, not the frequency. If an undistorted but faint sound can be heard, increase the volume of the source until distortion occurs. Then back it down a little. The volume can now be set using the receiver.

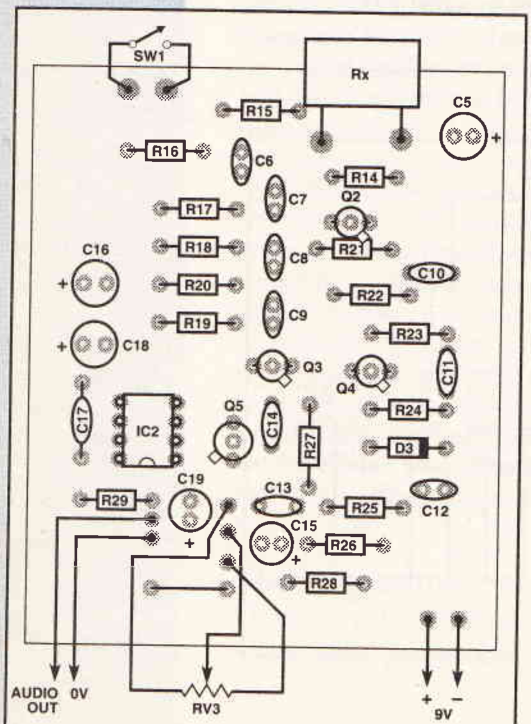


Fig.5 Component overlay for receiver

To lower the input impedance of the transmitter, a suitable valued resistor could be soldered across the tags on the jack socket.

PARTS LIST

TRANSMITTER

RESISTORS

R1	1k
R2,9,10	33k
R3	22k
R4	100k
R5	180k
R6	2k2
R7,8,11,12,	4k7
R13	10k
RV1	1k min horiz preset
RV2	470k min horiz preset

CAPACITORS

C1	470n
C2	47µ Elect
C3	2µ2 Elect
C4	180p ceramic

SEMICONDUCTORS

Q1	BC179
D1,2	1N4148
ZD1	2V5 reference diode
IC1	LM13700N

MISCELLANEOUS

40kHz Ultrasonic Transmitter
SPST Toggle switch
3.5mm mono jack
Case with integral compartment for PP3

RECEIVER

RESISTORS

R14	1M
R15	2k2
R16,18	5k6
R17	12k
R19,20	22k
R21	4k7
R22,23,24	10k
R25,26,27	100k
R28	3k3
R29	3R3
RV3	10k log pot

CAPACITORS

C5,18	100µ Elect
C6,7,8,9	1n Ceramic
C10,14	220p Ceramic
C11	100p Ceramic
C12	4n7 Ceramic
C13	470p Ceramic
C15,16	10µ Elect
C17	47n poly
C19	1µ Elect

SEMICONDUCTORS

Q2	BC109C
Q3,4,5	BC107
D3	1N4148
IC2	LM386

MISCELLANEOUS

40kHz ultrasonic receiver transducer
SPST toggle switch
3.5mm stereo jack
Case with integral battery compartment

Natural Oscillations

by A P Stephenson

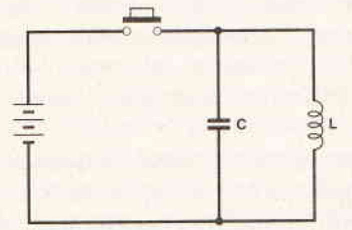


Fig.1 Natural Oscillations

An AC generating voltage connected across a circuit containing inductance and capacitance can, if the frequency is resonant, produce large increases in either voltage or current values. These oscillatory surges under resonant conditions are termed 'forced' oscillations because they rely on the continued presence of the supply generator.

In contrast, 'natural' oscillations require only a momentary spike of energy to start them off. Figure 1 shows an inductance, L in parallel with a capacitance C. A momentary touch on the spring-loaded push button provides the initial spike by placing a charge on C. Oscillations then continue without further aid until the energy contributed by the spike is squandered by resistive and radiation losses. Because consecutive cycles are diminished in amplitude, such oscillations are said to be 'damped'. If the inductance and capacitance were both pure, the natural or 'free' oscillations would theoretically, continue for ever.

Pure Inductance

High quality capacitors are virtually loss-free but to construct a pure inductance, that is to say, one without associated resistance and self capacitance, is to say the least, difficult. Immersion in some form of freezing medium such as liquid nitrogen can reduce the resistance to zero by inducing superconductivity but the self capacitance would still remain. In spite of the practical difficulties, the concept of a pure inductance is useful when discussing natural oscillatory action.

The Pendulum Analogy

The simple pendulum shown in Figure 2 can be persuaded to execute either natural or forced oscillations so it provides a useful mechanical analogy. Under normal conditions, the bobbin remains stationary at point B — the state of minium energy. However, if pulled backwards to position A, the system has been given potential energy so is no longer stable. On releasing the bobbin, it falls back towards point B but, because it now has kinetic energy, it overshoots and carries on towards the corresponding starting position on the opposite side, point C. But it now has potential energy again and is as equally unstable as when it started. The pendulum will therefore swing backwards and forwards due to the continual interchange of potential and kinetic energy.

Natural Oscillations

If both the friction at the point of suspension and air resistance are assumed zero, the pendulum will be free to oscillate indefinately.

To a first approximation, the period, T, of the swing is given by:

$$T = 2\pi\sqrt{l/g}$$

where l = length of string
g = acceleration due to gravity

The formula is reasonably accurate providing the amplitude of swing is small. The value of g at the earth's surface is usually taken as 9.81 m/s/s but decreases with height. Although open to the charge of hair-splitting, the g force on the bobbin is slightly lower at the extremes of swing than when passing through the lower middle point.

In practice, the losses, due perhaps to a rusty pivot and/or air resistance, will cause the amplitude of swing to gradually decay towards zero.

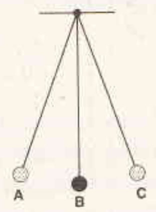


Fig.2 Simple Pendulum

Interestingly, the approximate equation for oscillatory period in the pendulum has a similar appearance to the corresponding approximate formula for the tuned circuit.

$$T = 2\pi\sqrt{LC}$$

Forced Oscillations

If someone (or some agency) gives the bobbin slight pushes every now and again at the 'right time', the pendulum is driven into a state of forced oscillation. As every child quickly learns, a swing can only be kept in motion with minimum effort if the pushes are sychronised with its natural period of oscillation. In electrical terms, the frequency of the alternating supply must be in resonance with the inductance and capacity of the circuit.

Natural Oscillatory Frequencies

So much for the pendulum! It is time to return to electrical oscillations and, in particular, the frequency at which they operate. It is convenient in the first instance to assume the circuit contains idealised inductance, i.e. without resistance.

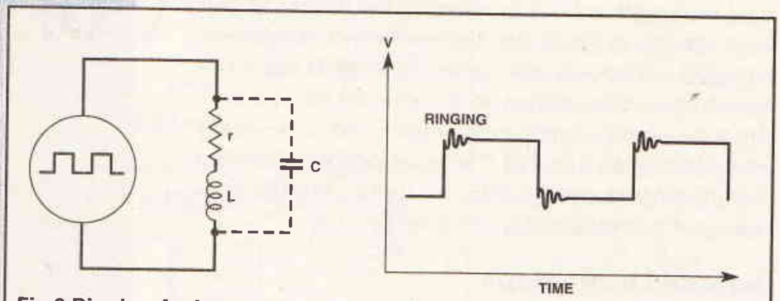


Fig.3 Ringing Action

Perhaps the most well known formula in electrical work is that which presumes to give the frequency of 'tuned circuits'. (Unfortunately, it is only strictly accurate for series resonance.) However, it's the one that runs as follows:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Since the inductance is assumed to be free of resistance, the equation is easily derived by considering energy interchanges alone. Referring back to Figure 1, a momentary touch on the push-button charges C to the battery voltage V. This provides the initial store of electric energy W, given by:

$$W = \tfrac{1}{2}CV^2$$

A quarter of a cycle later, the energy is transfered to the inductance in magnetic form:

$$W = \tfrac{1}{2}LI^2$$

Because there is no resistance to worry about there can be no energy losses during the interchange so it is permissable to equate the two energy forms by writing:

$$\tfrac{1}{2}LI^2 = \tfrac{1}{2}CV^2$$

The oscillations will be sinusoidal in character so the following simple formula for current can be borrowed from classical A/C theory:

$$I = V/\omega L$$

By juggling these two equations around using schoolboy algerbra, both v and L can be eliminated to leave:

$$\omega = \frac{1}{\sqrt{LC}}$$

or

$$f = \frac{1}{2\pi\sqrt{LC}} \quad \text{.......... Equation 1}$$

Practical Conditions

Things are not quite so straightforward in practical circuits when there is resistance to be taken into consideration. It follows intuitively that the oscillations can no longer continue indefinately. Current passing through resistance causes heat and, since heat is a valuable commodity, it must be paid for at the expense of oscillatory energy. Consequently, the amplitude of each oscillating surge of current decreases each time it passes the resistance. Like the pendulum with its rusty pivot, they are damped oscillations and will eventually die out altogether.

There is a general equation for damped oscillations which, although of revolting appearance, is surprisingly descriptive providing it is taken a bit at a time. Here it is:

$$v = V_p e^{-RT/2L} \sin(\sqrt{1/LC - R^2/4L^2}\,T) \quad \text{.......... Equation 2}$$

where V_p the peak voltage value at the start

v is the instantaneous voltage at any time, t, after the start.

There are three separate parts to consider:

1. The amplitude factor

This is the part played V and represents the original voltage to which C was charged.

2. The decrement factor $e^{-RT/2L}$

This function determines the rapidity with which the oscillations decay to zero. Note that as time, T, progresses, the amplitude of each swing, decreases exponentially. It will also be evident from a glance at the decrement factor that oscillations decay quicker if R is increased or L is decreased. At the start, of course, T = zero so the decrement factor is initially unity because e = 1.

One consequence of the exponential nature of the decay is that the amplitude ratio between cycles is constant. For example, taking three consecutive cycles A,B and C: if the amplitude of B is 0.9 of A, then the amplitude of C will be 0.9 of B and so on. If this is followed to its logical conclusion, a damped oscillation will never die out completely — but then this is really hair- splitting with avengeance!

3. The frequecy factor

The general equation for a sinusoidal waveform is:

$$V = Vp \sin \omega wt$$

Comparing this with Equation 2, it can be taken that the terms under the square root sign correspond to ω and since ω = 2π. it can be taken that the frequency formula for damped oscillations will have the form:

$$f = 1/2\pi\sqrt{(1/LC - R^2/4L^2)} \quad \text{.......... Equation 3}$$

This shows that the well known formula for frequency (given earlier under the label Equation 1) is not quite accurate because Equation 3 shows that the frequency is slightly lower by the square root of $R^2/4L^2$. The difference is slight because R/L is much smaller than l/LC so, in most practical cases, the simple formula provides sufficient accuracy. However, the fact that a damped oscillation runs slightly slower than the equivalent loss-free version is interesting if only to give additional credence to the pendulum analogy. A pendulum with a rusty pivot (which we have previously assumed to be the analogue of resistance) must surely swing slower than one boasting a rust free version!

Critical damping

Examination of the terms within the square root of Equation 3 raises the spectre of imaginary numbers. What happens if $R^2/4L^2$ happens to be greater than l/LC ? The answer, of course, is that the result will be the square root of a negative number which prominant mathematicians tell us are imaginary. So the conclusion is that the oscillations would also be imaginary - perhaps they exist in the spirit world! In common sense terms, free oscillations can only exist if R /4L is less than l/LC. By rearranging, we can arrive at the value of the critical damping resistor:

$$R = 2\sqrt{L/C}$$

Damped oscillations can only exist if R is less than this value.

Examples: If L =40mH and C =10nF, a few cursory key presses on a calculator will show the critical damping resistance to be 4k.

Wherever there is stray inductance in a circuit, damped oscillations have a habit of butting in where they are not wanted to this equation can be used to find a suitable resistor value to kill them off. The above has assumed that R is in series with the inductance but oscillations can also be critically damped by connecting a resistor is parallel with the LC circuit providing the equation is modified as follows:

$$R = \tfrac{1}{2}\sqrt{C/L}$$

This is the upside down version of the series damping resistor. When a steep-sided pulse, such as the edge of the rectangular wave show in Figure 3, hits an inductance, damped oscillations may be shock excited due to the presence of stray capacitance. This is called 'ringing' and is usually an undesirable phenonemon. The nuisance can be prevented by slapping in a critical damping resistor somewhere. Stray capacitance is often difficult to measure so amateur designers, particularly the less reputable species like myself, may be tempted to fall back on trial and error methods.

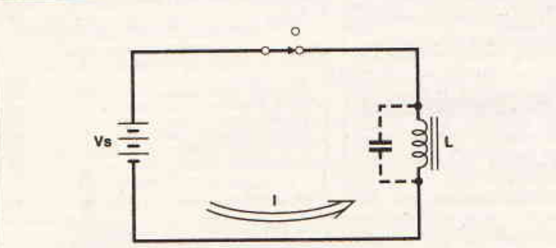


Fig.4 Breaking an inductive circuit

Breaking An Inductive Circuit

Figure 4 shows a coil of inductance. L, with resistance, R, (which might be the coil resistance or an actual resistor) connected across a DC supply via a switch which has been closed for some time. The steady DC current flowing is given by ohms law:

$$I = Vs/R$$

The current sets up a steady magnetic field around the coil representing a store of energy, W, given by $W = \tfrac{1}{2}LI^2$.

According to a certain gentleman by the name of Faraday, when the switch is suddenly opened, the change of current (from something to nothing) will cause an induced voltage to appear from out of the blue. Apparently, coils don't like their current to be interrupted so it can be assumed that this voltage —which can reach lethal proportions in large coils —is a sign of their displeasure.

The question is, how high is this voltage? Since the capacitor C is in parallel, the induced EMF will charge it to the same potential and will therefore have the same stored energy, $W = \tfrac{1}{2}CV^2$ so it is permissable to equate the two energy forms:

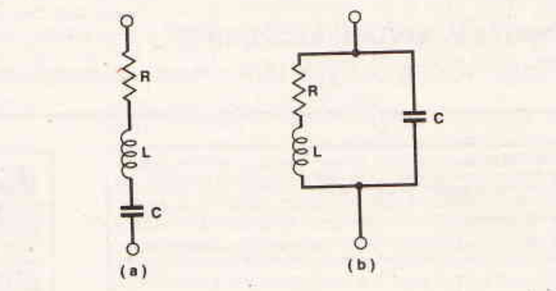


Fig.5 Resonant Networks

$$\tfrac{1}{2}CV^2 = \tfrac{1}{2}LI^2$$

By juggling the terms around, the induced voltage turns out to be:

$$V = I\sqrt{L/C}$$

The presence of the resistor has been ignored but it will not seriously affect the above result.

Some idea of the order of magnitude expected can be gained by considering a couple of examples.

Example 1. Let L = 0.1H, C = 1nF and I = 0.1A. Plugging these values into Equation 4 yields a result of 1kV.

Example 2. Let L = 12H, C = 0.3nF and I = 10A. These values have sinister overtones because plugging them in to the equation shows that anyone opening the switch should wear thick rubber gloves if they happen to be allergic to 2 million volts! Fortunately, it is doubtful if coils of 12H with only 0.3nF are likely to be kicking around in the spares box. Neverthe less, the example may act as a timely warning to anyone foolhardy enough to play around with large coils carrying high DC currents.

The high voltage appearing when the current is interrupted is actually the first half cycle of a damped sine wave. Subsequent cycles will decay towards zero in accordance with the exponential decrement factor.

An annoying feature of induced voltages is the damage caused to switch contacts. Conventional electromagnetic relays or indeed any device containing a switch and a reasonably large inductance are particularly vulnerable. According to the equations, the induced voltage is inversely proportional to C, indicating that the voltage can be cut down to size by connecting a largish capacitor somewhere in the circuit.

Resonance

The term 'resonance' has nothing to do with natural oscillations. It is used in connection with tuned circuits driven by a sinusoidal EMF source. In other words, it is applicable only to forced oscillations. Although there are several definitions of resonance, some tend to be too narrow and others can be misleading. The following is a universally applicable definition:

Any network containing a mixture of reactive components is in resonance if it behaves to the EMF source as a pure resistance.

Series Resonant Frequency

Figure 5a shows a series LCR network. Although the resistance is shown as a separate component to the inductance, it is normally the unwanted internal resistance.

The resonant frequency can be found using the familiar Equation 1 mentioned earlier. It is accurate for the series network and is repeated below:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Parallel Resonant Frequency

Figure 5b shows the usual form of a parallel connected LCR network. Although the same formula is still commonly used for the resonant frequency it is not quite accurate. The following is the correct version:

$$f = 1/2\pi \sqrt{(1/LC - R^2/L^2)}$$

However, R/L is usually much less than 1/LC so it can be assumed zero, in which case the equation reduces to the simpler version.

Conditions At Resonance

In general, the series resonant network magnifies voltage by a factor called 'Q' while the parallel network magnifies current by the same factor.

There are many other properties of resonant networks but to discuss them here would mean encroaching on a large area which properly belongs to basic AC theory.

AutoMate 20 Mixi

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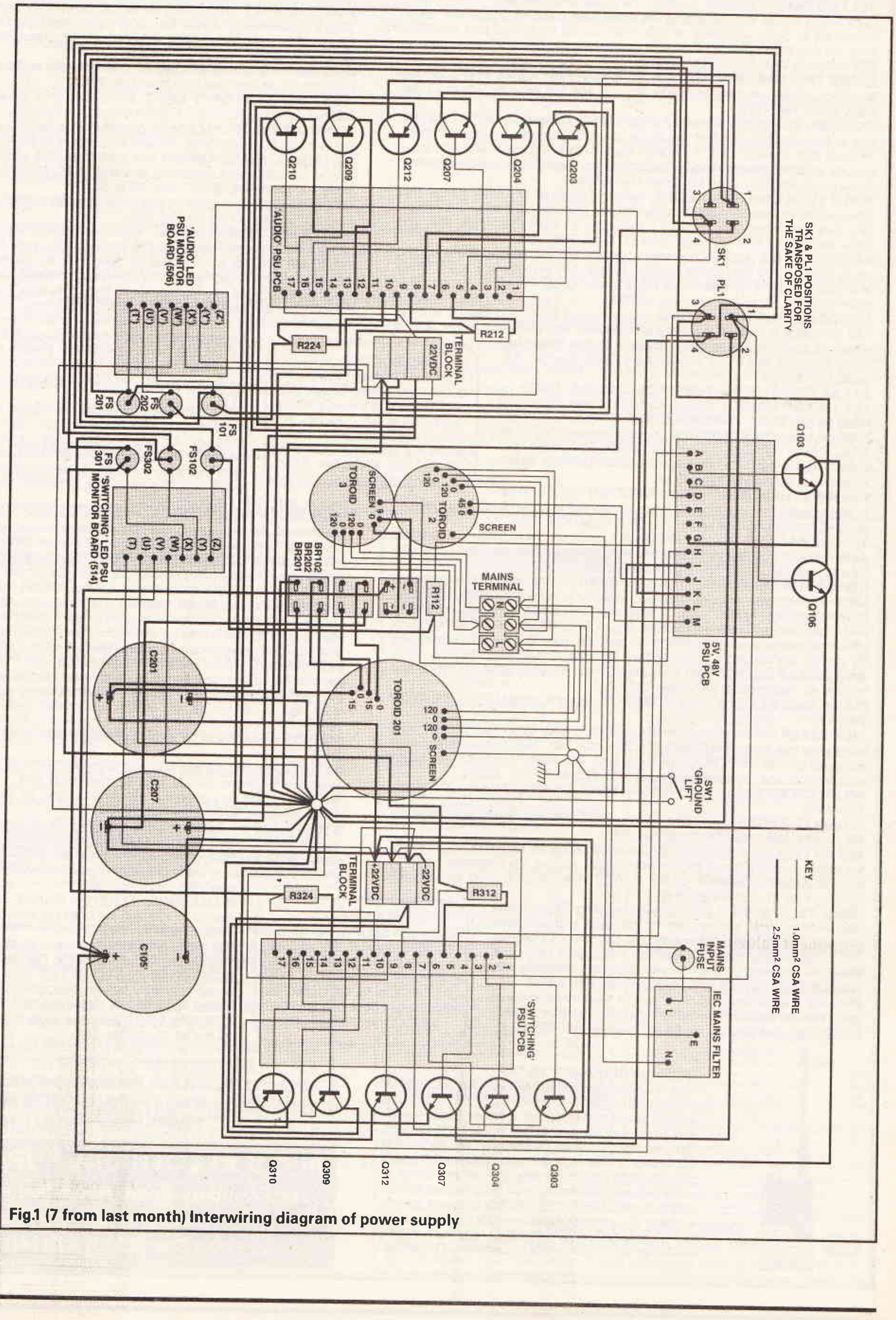


Fig.1 (7 from last month) Interwiring diagram of power supply

ng Desk

by Mike Meechan

We are now around a quarter of the way into this series of theoretical and constructional articles centred around the Anniversary AutoMate modular mixing system. I know that some of you may be impatient for more construction and less idle, theoretical chat. I should perhaps explain more fully the underlying strategy of this series and then a new light may dawn and you shal l all be able to see why I have approached the project with this slightly unconventional philosophy and unorthodox manner. When I were a lad —strains of the Hovis advert music are heard in the background —beer was a penny a pint times were hard and after returning from't eighteen hour shift at pit, one would relax with some soothing electronic project work. starting out as a raw beginner with no formal education in the subject bar "0" Level or Higher physics it was difficult to find good useful projects with understandable blurb attached. I know, I know, there do exist text books and tutorials on every conceivable aspect of electronics but many seem distant and remote from the practical world. In fact, I don't think that it would be too far off the mark to say that in some cases, the textbook descriptions are downright offputting with reams of complicated maths reading to a solution which seems to have little or no application in a real circuit or a tangible system. It is probably true in most of us that the subjects which we are most likely to understand are those which we enjoy or which relate to aspects of a hobby or pastime which we pursue — ie a practical realization of a sometimes abstract idea.

Design Philosphy

What I wanted to achieve with the AutoMate series was a text - a design tutorial, if you like —which would attempt to unravel some of the complexities of audio engineering whilst presenting it within an interwoven framework of true practical examples qv the AutoMate console. In this way, the reader can see for him/herself why certain techniques are employed, circuit configurations used and component values optimised. The considerations to be made and equations necessary to make these are presented within the article so that the reader can use them to satisfy him/herself that what is presented is the best way to realize a given electronic function. Detailing all of the necessary information in this way will then allow interested parties the opportunity to do-it- yourself with a greater degree of confidence. This seems to have been a much-neglected aspect of many otherwise interesting, informative or educational electronic prose. I guess that in many respects, knowledge is power, and to retain this knowledge is to dominate intellectually within a given field. A lot of circuit design is intuitive —once a certain level of background knowledge has been established — and good and bad design techniques are most often gleaned from practical construction and analysis of real circuits. However, I think that it DOES make for interesting and varied reading to take an in-depth and mathematical look at the factors involved, so long as this is tempered with commonsense, and a predominantly practical approach to the circuit complexities is adopted throughout.

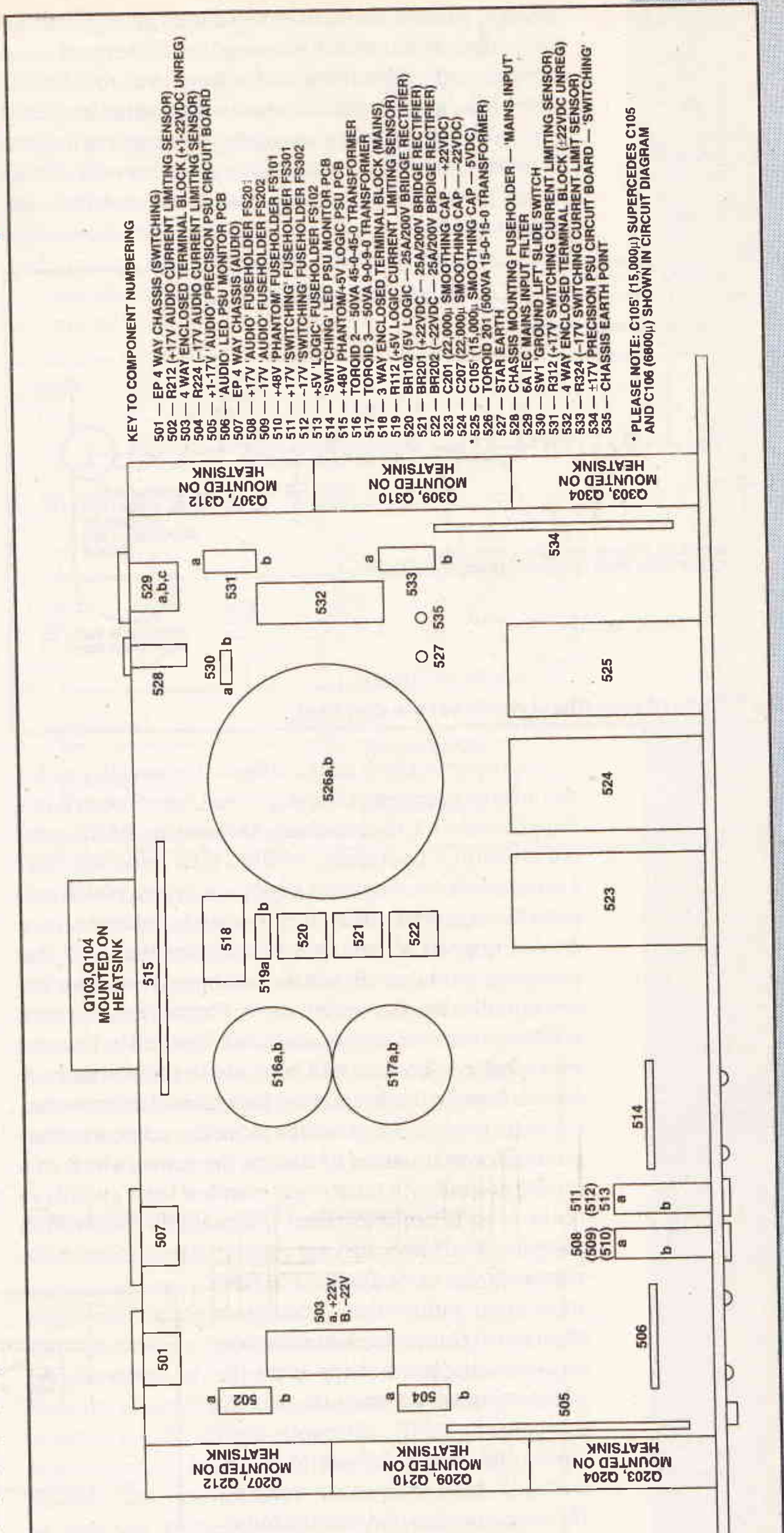


Fig.2 Positioning of components in power supply

In any event, it would some rather nonsensical to publish PCB layouts and constructional details for the separate parts of the input channel until all of the different configurations within it are explored. There are some ten different permutations of effects available on the Mono Mic/Line channel alone. It would rather be akin to buying the bricks before measuring the length of the wall were we to show individual overlays before such time as all of the possible options had been explored and documented.

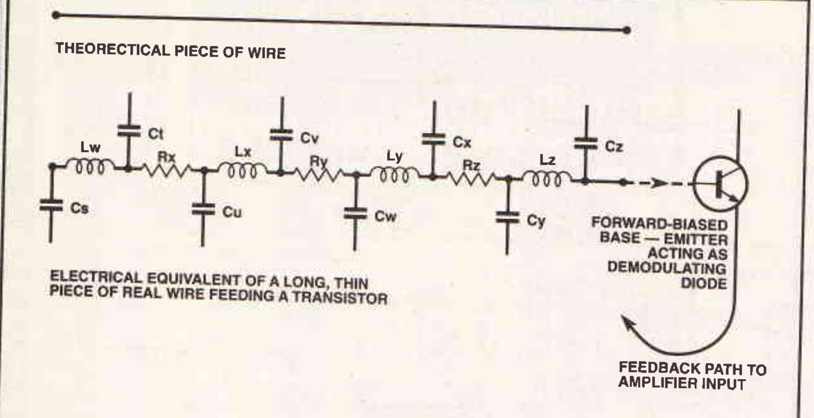


Fig.3 Piece of wire (theoretical) versus practical

As a parting note on this subject, the circuitry within the mixer can be roughly categorised into 6 main types. Amplification, EQ, Switching, Monitoring, Mixing and Automation. The circuitry within a fully-endowed Mic/Line module encompasses all of these types. Whilst progress through this first featured module is somewhat ponderous, once all of these topics have been discussed, that particular module built and the text moved on to the Stereo module, the Group/Monitor, Output etc, the pace will be correspondingly much faster. This will be because only simple references will be made to previously-published chapters for the relevant background information.

The larger the system, the more the scope for error grows. In certain areas of design, the error (which in a mixing console will most likely manifest itself audibly as noise, crosstalk or distortion) is cumulative. It therefore pays dividends to design any error (noise etc) out of the system as far as is practicable from stage one, rather than attempt to eliminate it from a much more hostile environment (in the shape of the finished sub-module, module or even the console itself). To quote Steve Dove, one of the authors to whose article I have frequently referred, "Mixing consoles and understanding them is the key to professional audio".

Whilst on this aspect, I should also say — and I am not in the least ashamed to do so — that during the course of the research and development of this project, I have consulted and referred to some of the best textbooks available on the subject of audio engineering. Many of the books and articles are authored or edited by engineers and technologists reckoned among their peers to be the most knowledgeable in the world in one or more particular fields within the discipline of audio engineering.

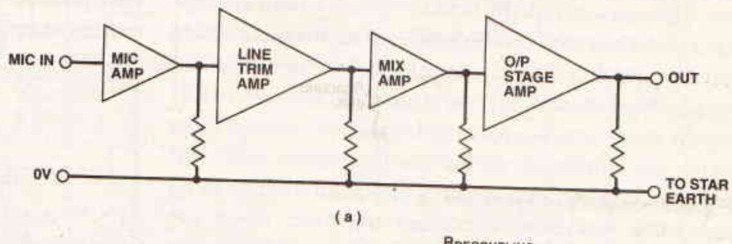
Anyway, enough of the self-gratification and back to the matter in hand.

Earthing

We can see from the circuit diagrams of Part 2 and the PCB and components were very carefully and methodically earthed. Figure 7 —which, unfortunately, space did not permit us to print in the June issue —shows the main wiring diagram of the power supply unit. It is apparent that I deviated from the normal convention for circuit diagrams and showed a view of the earthing arrangements as an almost exact representation of the physical layout on the PCB. A very comprehensive depictation of all of the PSU earth wiring was given in last month's issue. This was intended to illustrate some of the aspects of earthing which I am going to make a little clearer here and now. Sound 'ground rules' as they might be termed are imperative to the stable and noise-free operation of any audio circuitry, be it power supplies, amplifiers, FX units or whatever. These rules take on special significance when viewed in the context of designing a massive, interconnecting audio system such as might be constituted by a typical mixing desk. It might be wise at an early stage to discuss the subject further since all that is listed here can be taken as representative of the techniques which should be employed in any good audio design work. An early appreciation of the many factors involved in this process will stand the reader in good stead and allow him/her to be more receptive of some of the outlandish lengths to which an audio engineer must go in each of the various modules —and the console as a whole —in order to create a workable and hum-free system.

For a proper understanding of the complexities of the subject to be realized, the very concept of earth, ground, 0V or whatever one might care to call it needs to be understood. As 0V is imperative to the correct working of all of the console, an early appreciation of the techniques will not be considered amiss as we progress further and deeper into the bowels of the AutoMate 20.

Ground is merely a reference to be used between



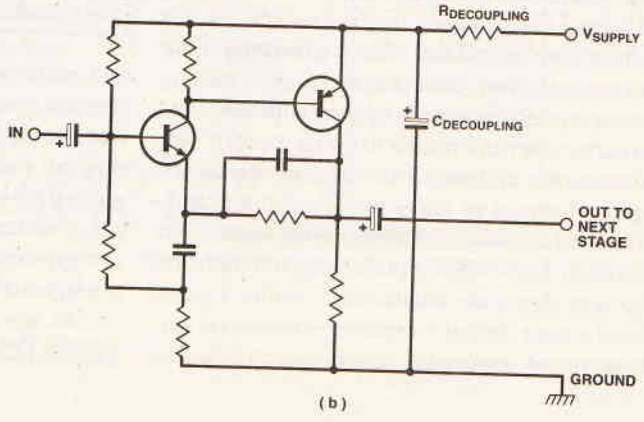


Fig.4a Ground follows signal arrangement of earthing
Fig.4b Decoupling of power supply line in unipolar active circuitry

PROJECT

interconnecting circuit elements, a reference which can be eliminated in a differential system. This being the case, why should it be that this reference should be of such paramount importance in the design of a console?

We should consider an ordinary, everyday, bog-standard piece of wire. which no matter what its length, whether long or short, will exhibit resistive properties. Popularly taught physics dictates that in accordance with Ohm's Law, any resistive element within a circuit which has a current passed through it must have a potential difference developed across it. This current passing through will create a magnetic field around the wire, which means that it has inductance, and if the wire resides in an area in close proximity to anything else, (ie not suspended in free space), it will exhibit capacitance.

Radio A Ga Ga

Our ordinary, non-resistive, non-capacitive, non-inductive piece of wire now begins to look more like the circuit model depicted in Figure 3, and might easily be confused with something much more familiar to an engineer working in an RF design environment qv an aerial, bandpass filter or transmission line. This is a good analogy, since many active devices used within the mixing desk circuitry will have bandwidths which extend to the 100's or 1000's of kHz region. This is significant because of the horrific amount of RF energy flying around the atmosphere, be it radiated from computers, dimmers, ham radio, cellular phones or whatever.

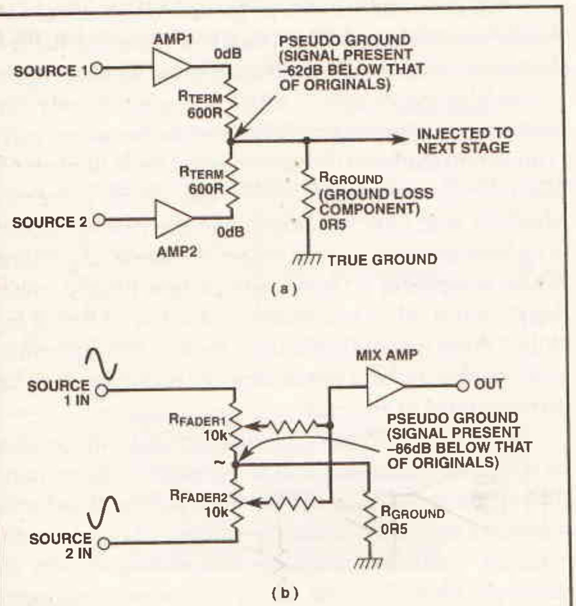


Fig.5a Crosstalk at an amplifier output
b Crosstalk at an amplifier input

Our simple piece of wire now has the rather dubious distinction of being capable of demodulating RF energy and rendering it audible, as the RF signal is able, in this arrangement, to enter the amplifier input through any by-passed feedback component where it can be subsequently demodulated by the amplification circuitry employed since any forward-biased transistor junction will behave as the rectifying element necessary to demodulate the RF.

The two main points to note from this are that the reactive components give rise to demodulation stability and RFI problems whilst the resistive elements cause the hum loops so dreaded by engineers and listeners alike. On this RF note, it is interesting to analyze ground effect problems due to the reactive nature of any piece of wire. No matter what its length, there will exist some frequency in the electromagnetic spectrum at which the piece of wire will present a quarter wave length pathway. This is a much neglected aspect of low-level input stage design and explains why one is able, via the badly engineered hi-fi preamp, to tell exactly how late the local taxi service is running!

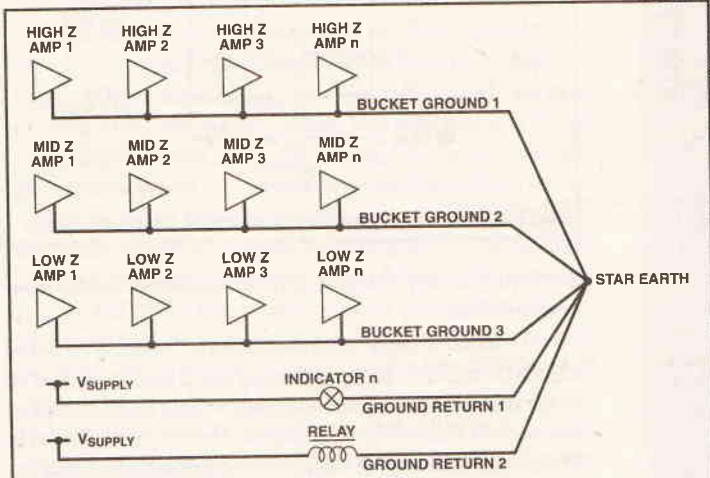


Fig.6 'Bucket' grounding techniques

Why ground anything to earth in the first place, since with careful regard to the internal referencing of the equipment, it will function regardless - many non-earth referenced pieces of electrical apparatus work quite adequately without them. Nevertheless, a system comprised of many separately powered modules is almost certain to hum or oscillate since there will exist within the system any number of differing self-generated 'reference' voltages at various points along the signal pathway, meaning that noise-inducing current will be sourced or sunk.

Establishing Good Connections

A well-established remedy is to swamp all of these (relatively) high impedance paths with a connection to a zero ohm impedance (which, to all intents and purposes, the earth is). Despite these precautions, there may exist in the ground wiring of the system other small noise currents since the ground lines will have finite impedance causing noise pd's to be develop across them. These unwanted noise currents can then infiltrate the wanted signal. Balancing of the signal is therefore considered to be a universal solution to the problem, as is the grounding of the chassis to earth, this approach offering as a bonus some protection against harmful and potentially fatal shocks from the mains supply.

The grounding techniques utilized in high quality sound studio construction are fairly typical of those employed within a console wiring system. Substantial cabling is necessary so the earth is effective and efficient and also, that any voltages developed because of finite cable impedance are small in relation to the wanted signal at that point. All equipment is mechanically earthed from the bay housing all input, break and output connectors —the single connection eliminates earth loops —and

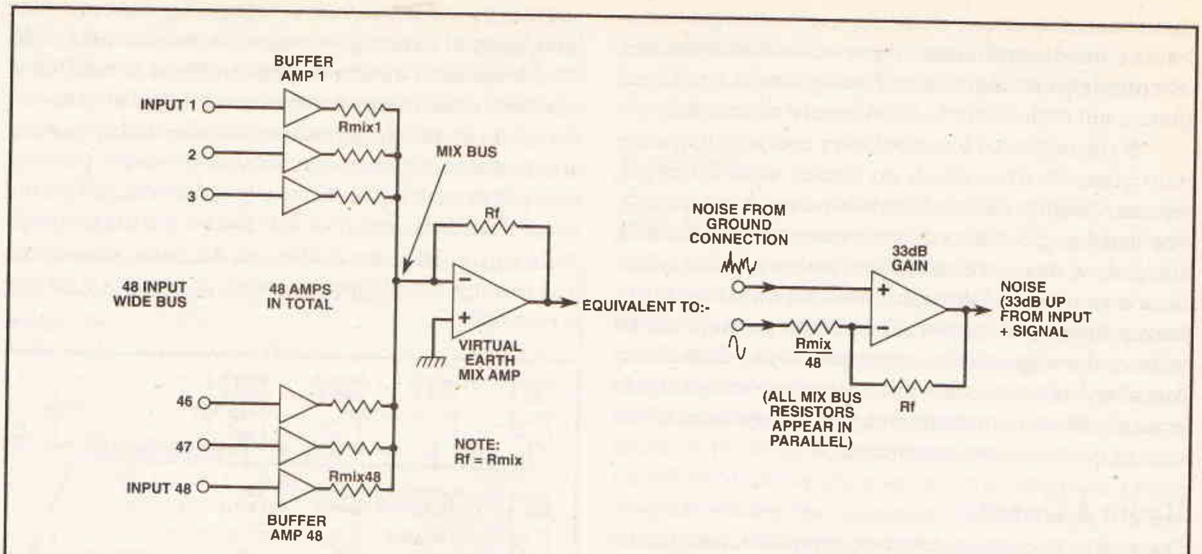


Fig.7 Ground problems in the virtual earth mix amp

microphones are earthed only through their studio connector boxes.

Two electrically separate earths are employed in the studio complex —mains or safety earth and technical or programme earth. Never the twain shall meet except at the central studio earth point or, in the case of a large multi-studio complex within a broadcasting organization, at the point where the earth for the entire building is derived. The central earth point in this latter instance will consist, literally, of a very large and expensive piece of copper or equivalent driven some distance into earth so that it contacts damp subsoil and resultant continuity is good.

Lifting Oneself Off The ground

Where both earths must be present in the same enclosure (as in the case of a wall-mounted microphone box mechanically connected to safety earth, the two earths must remain separate if hum loops are to be avoided. This may mean that connectors are isolated from mounting plates using insulating washers or equivalents. From the power supply unit wiring diagrams, it can be seen that a very similar approach is adopted, with the switching (logic) and audio earths being kept entirely apart and only joined at one point — the system star earth. This point then connects to the chassis safety earth through the ground lift switch which means that both can be made to be electrically isolated from each other. This can cure an hum loop problem when other, outboard processing equipment is connected to the console. Other peripheral equipment may not employ such stringent earthing techniques and earth and programme earth may, in fact, be connected together. If this is the case, and the power supply ground is also connected to mains safety earth, we can see that a dreaded hum loop has been created. I have mounted this switch inside the enclosure since I take the cynics' view that what is not available to touch on the outside of the unit cannot be reset or tampered with by unauthorized personnel. This philosophy extends to my never including any mains switch or master reset type control on the front panel since it will be found that these controls are operated at the most inopportune moments! In any event, if mains isolation of the unit is required, for instance, in the circumstance of it needing to be serviced, this isolation should be afforded by removing the mains connection to it. Furthermore, my console operates in a very controlled environment where any connections to the mixer are made under my supervision and direction. Certain operating conditions might necessitate the ground lift switch being made more readily accesssible and if this proves to be the case, the switch could then be mounted on the rear panel.

Whist on the subject of ground lift switches, one home-produced amplifier which I once had the dire misfortune to examine achieved this ground lift effect by disconnecting the chassis — which was permanently connected to 'programme earth' - from mains safety earth. This action rendered the chassis —and more importantly the user — completely free of any shock protection should a fault have developed and the chassis become live. Similar practises exist within the world of guitarists where some seem to try to eradicate hum by disconnecting the earth safety connection inside the 13A plug top. All of these methods eliminate hum at the rather high price of also perhaps eliminating the musician. They are to be avoided at all costs!

On a slightly lighter note, no-one wishes a repetition of a scenario which seemed to occur in umpteen soaps and crime series in the late sixties and early seventies wherein a musically-inclined member of the cast was dispatched — either deliberately or accidentally — to the heavenly choir because he or she was electrocuted through a dodgy mic/guitar/mixer/amplifier combination!

Within the console itself, problems in this area are, of course, compounded by a very large order of magnitude because of the number of low level voltages involved. If we consider a typical amplifier circuit, dependent for correct operation on an input signal voltage and reference —usually 0V —it is easy to see that if the reference should deviate in any way from a steady state voltage, this change will be seen as a corresponding deviation superimposed on the output signal of the amplifier. Put another way, any signal which the reference 'perceives' and which is not also common to the input —ie hum or noise —will be summed and amplified as it might have been had it been applied to the amplifier input by more conventional means. The obvious way to alleviate the problem is t ensure that the point to which the amplifier is referred is connected directly to the reference which the output of this same amplifier sees. Does this make sense? Afraid so. This philosophy of source reference/destination reference — which is used all along the signal path — is known simply as 'ground follows signal' and forms the basis of the grounding techniques which exist in just about all large commercial mixing desks. See Figure 4a. It was especially important in the days of discrete component amplifier stages where the signal 0V line was also the power supply return. The eradication of hum and noise caused by supply line induction was further complicated by the fact that the positive supply rail (effectively another low impedance) became another part of the nightmare and could only be eliminated from the equation by active decoupling using a series resistor/parallel capacitor arrangement. Effectively, this fed the susceptible circuit through an impedance much larger than that of the ground path proper. Figure 4b shows a typical arrangement.

The modern-day differential operation of active amplification circuitry (namely op-amps powered from split/bipolar supply rails) means that there is no audio current flowing through the ground connection. Other factors now begin to enter the equation from all sides. Insert points in the channel circuitry are almost always unbalanced, as are the many distribution networks which will feed the console. The scope for hum loops and instability rises in direct proportion to the number of facilities provided on the mixer and so other contingency earthing arrangements, such as star earths, must be made. The resultant earthing network tends, in the main, to be a mixture of the two with the most convenient method at a given point in the signal progression being the one employed.

To Much Talk On The Bus

Crosstalk is another not-unrelated inherent problem of the earthing arrangements within the console, amplifier or any other applicable piece of audio processing circuitry. We touched very briefly on this subject last month and mentioned the quite superb performance in this aspect of the true monoblock stereo amplifier. Refer to Figure 5a. Resistor R_{ground} represents the small resistive portion of the earth path wiring, loss resistance or whatever we wish to call it. R_{load} is the amplifier load at its output terminals and can either be a low impedance termination or a high impedance such as a channel fader pot. The node which represents the reference is now actually at some voltage above true ground since the network comprised of the two resistors forms a potential divider and so at this node there will be present an attenuated version — in the ratio R_{load}:R_{ground} — of the output signal of the amplifier. A low-Z termination — typically 600R — and a ground loss component in the order of 0.5R will mean that at the 'pseudo' ground node, a signal some 62dB below that of the amplifier output signal will now be present. This can then be injected into the input of any following amplifier circuitry through the pseudo ground path.

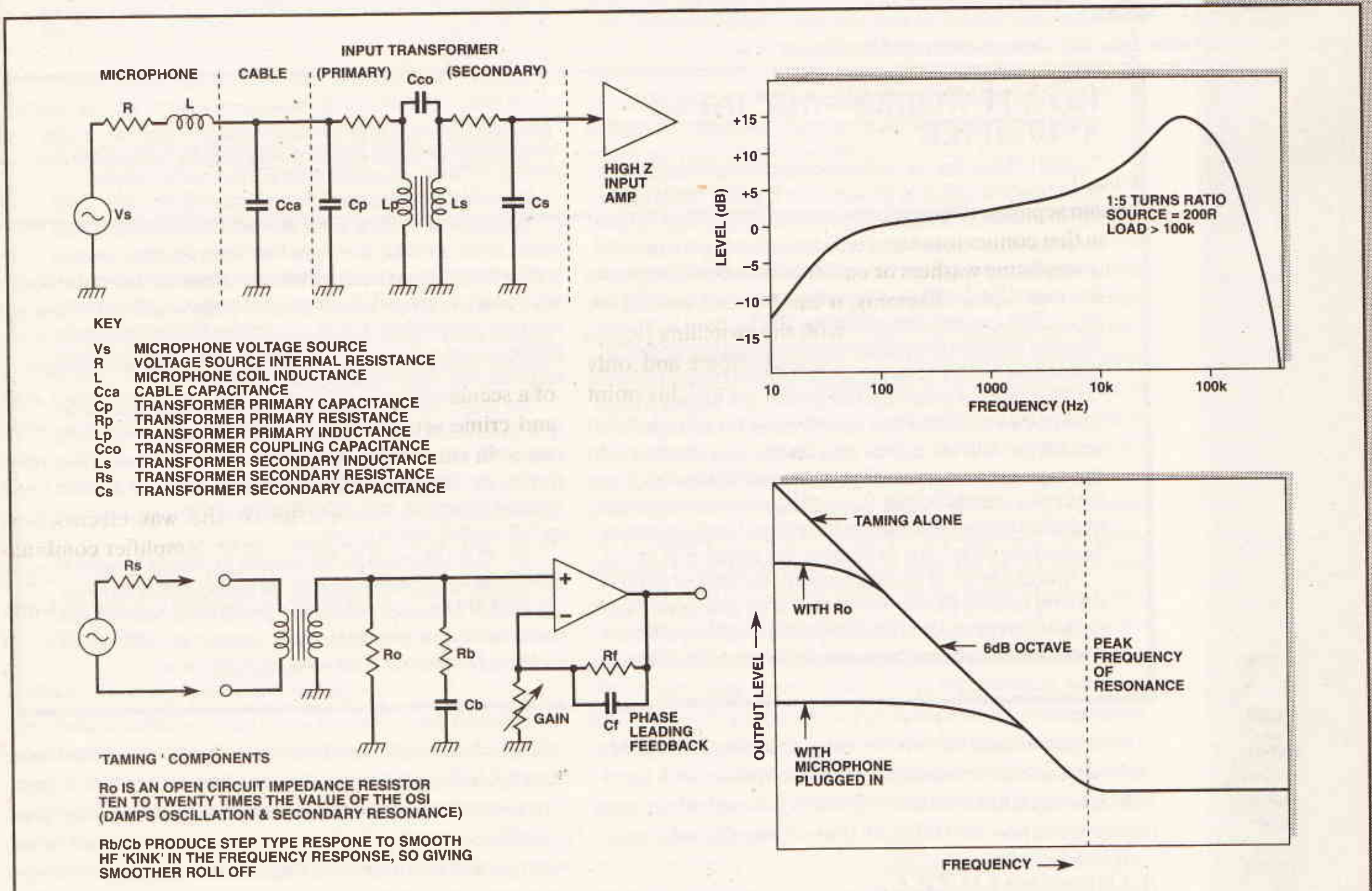


Fig.8 Circuit model of mic/cable/transformer combination

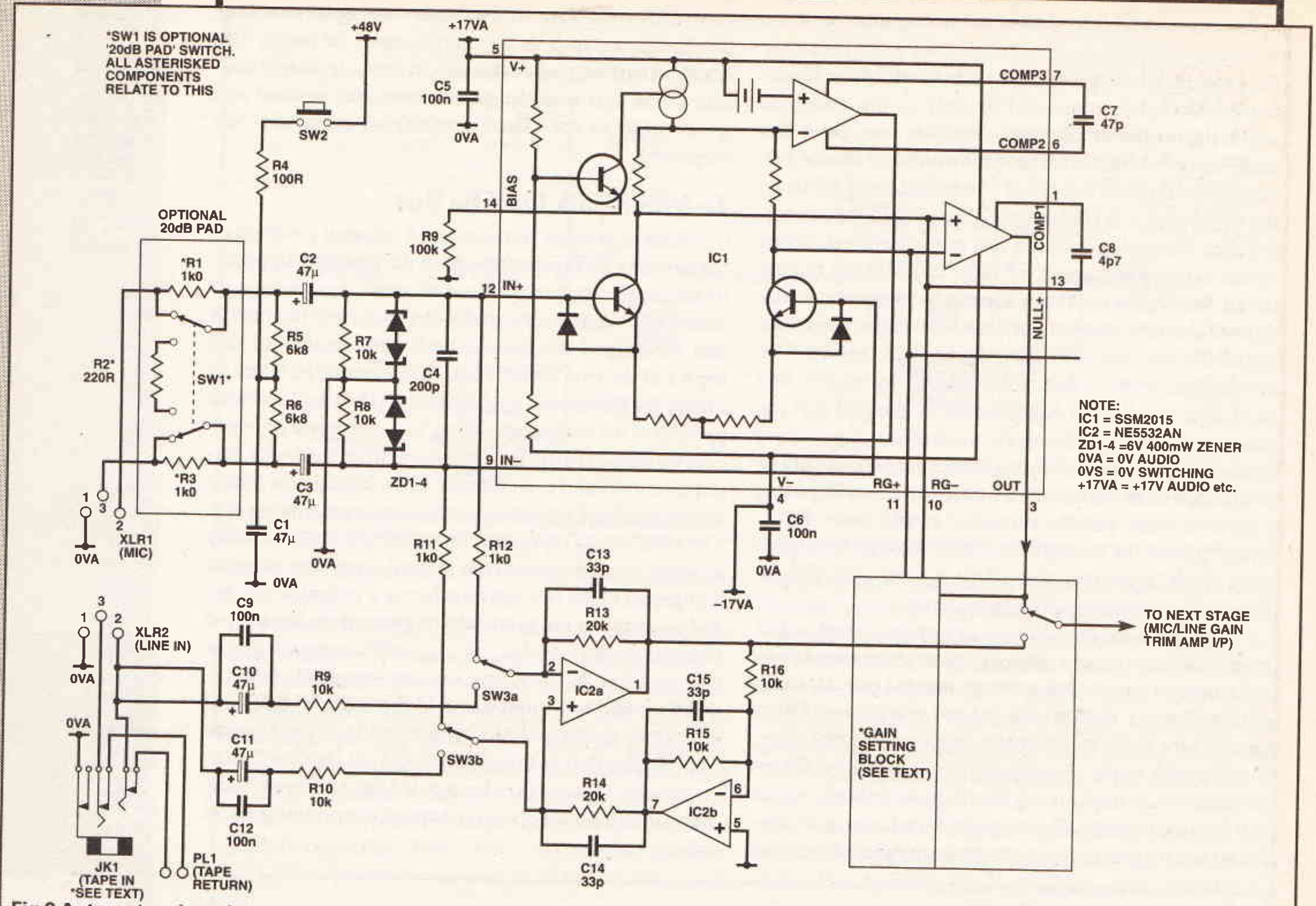


Fig.9 Automate microphone — mono balanced line input

HOW IT WORKS – MIC INPUT AMPLIFIER

The SSM 2015 is an ultra-low noise audio preamplifier particularly suited to microphone preamplification and gains from 10 to 2000 can be selected with wide bandwidth and low distortion over the full gain range. Its excellent performance is supplemented by the fact that it has highly symmetrical slewing rates which are optimum for large signal audio. The equivalent input noise of this circuit is about $1.3nV\sqrt{Hz}$ at maximum gain resulting in a 20Hz to 20kHz input noise level of 183nV, or -133dBU referred to zero level. This is over 37dB lower than a typical microphone output from the 30dB SPL ambient noise level in a typical room. Refer to the block diagram of the IC. The 2015 operates as a true differential amplifier with feedback returned directly to the emitters of the input stage transistors This system produces both optimum noise and common mode rejection while retaining a high input impedance. An internal feedback loop maintains the input stage current at a value controlled by Rbias. This provides a programmability function which allows noise to be optimised for a wide range of source impedances, the noise being within 1dB of the theoretical limit between 500R and 2.5k.

Rg adjusts the gain of the circuit from about 10 to 2000, the maximum gain being limited by the minimum resistance of the potentiometer. Good quality resistors are used in the gain setting network since low quality types, notably carbon composition, can generate significant amounts of distortion and under some conditions, low frequency noise. At gains below about 10, distortion and noise performance of the 2015 is somewhat degraded.

C6 provides compensation for the input stage regulator while C7 and C8 compensate the 'overall amplifier, their values being dependant upon the size, in turn, of resistor, Rbias. As we have already discussed, low noise amplifier design is always a trade- off between noise voltage and noise current. Normally, a compromise is chosen which produces optimum performance over a limited range of source performances. Rbias programmes the 2015 for optimum performance at source impedances up to 4k, noise being within 1dB of the theoretical limit between 500R and 2.5k.

The 'budget' input preamplifier is very similar in design although two op-amps are used to amplify the input, the SSM 2015 being omitted in this instance. The outputs of these are applied to a third op-amp which then amplifies the differential signal. Equivalent input noise and distortion figures are still very low, the E_{IN} being 760nV over the full audio bandwidth and THD less than 0.01% at full gain.

SW1, R2 and R3 provide the 48V necessary for phantom powering of microphones,- should this be necessary. The resistors balance the voltage across each of the two legs, the capacitors provide the DC blocking for the preamp input and the zener diodes provide transient over-voltage protection for the 2015 whenever microphones are plugged in and out.

A typical case of two identical sources sharing this ground point as a common reference means that there will be a cross injection or crosstalking of each of the two inputs at a level - 62dB below that of the original signal.

A Question Of ZZZ's

Now, taking the instance of the amplifiers feeding a typical high impedance source such as the 10k presented by a channel fader as in Figure 5b, the bogus crosstalk signal now present at the pseudo ground is at a much lower level (-86dB) since the high impedance of the fader now swamps that of the ground loss resistor. The high impedance termination, however, is much more likely to suffer from radiated crosstalk injection than a low impedance source.

HOW IT WORKS – LINE INPUT STAGE

This is again very similar in design to the microphone input stage, the 2015 input stage now able to be omitted because the noise and gain considerations of this 10k bridging impedance input no longer require the esotoric performance of this device and low noise op- amp stages suffice. The use again of close tolerance resistors affords us very good common-mode rejection.

A one op-amp differential stage cannot be used in these circumstances. Referring to Figures 10a,b and c, we can see that these are all classic, differential-style instrumentation amplifiers with resistor values altered so that the requirement for 10k bridging impedance on the input can be met. Large value resistors on the inputs necessitate the fitting of large and unpolarised capacitors — used as DC blocks — so that no attenuation or phase distortion results because of RC filtering action. Unfortunately, simple, one-amplifier circuits such as these work only under ideal conditions since the large disparity in the values of impedances of the inverting and non-inverting inputs – as we have already briefly mentioned – causes problems since one is set by the external resistor values while the other is essentially very high.

A simple analysis of the circuit under typical input signal conditions should serve to highlight the problems which we can expect to encounter when using these simple circuits as a line input stage.

We shall apply a varying signal to one input at a time whilst the other is left unconnected to our signal source. For signals applied to the inverting input, impedances around the op-amp are equal and it behaves as a unity gain inverter as the non-inverting input is, to all purposes and intents, grounded. However, applying a signal to the non-inverting input causes the inverting input reference to change because the impedance, by virtue of the fact that it is being variably boot-strapped by common-mode and non- differential voltages, will change also.

Impedances to both inputs can be arranged in such a way that both halves of the differential signal are inputted to the amplifier via defined resistors, but this is at the expense of common-mode performance since there is a serious conflict between trimming the op-amp for good common-mode rejection and trimming it for good differential gain. Balancing impedances ruins CMRR and optimising CMRR imbalances impedances to such an extent that if the source impedance is considerable, instant imbalance results. This is because the source impedance simply adds itself to the carefully optimised values of input and feedback resistor. A simple and quite elegant solution to the problem is shown in Figure 11a. This separately buffers the inputs to the differential amplifier and consequently requires three op-amps. Figure 11b shows another circuit which eliminates one of the three op-amps at the expense of creating an input which, although truly differential, is not fully 'floating' with respect to ground. For an active

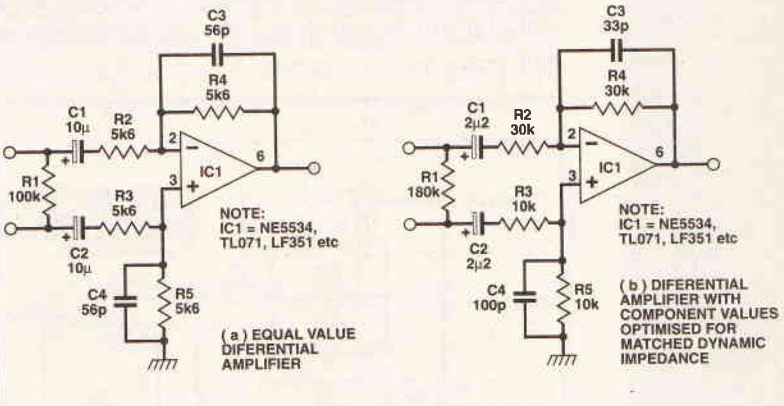


Fig.10 Single op-amp differential input amplifiers

input stage to compete successfully against its transformer rival, it must, as the transformer is, be impervious to any imbalance in the termination at the input, ie there should be no drop in output level should one of the input 'legs' be shorted to ground, as might be the case when an unbalanced signal source is applied to the input. This is known as the 'floating' test.

The line input stage offered here is a cunning two op-amp configuration as shown in Figure 11c which negates the input impedance disparity of the single op-amp circuit while offering a good CMRR and fulfilling all other criteria as already specified. It is known simply as the 'Superbal' and is a balanced differential virtual-earth amplifier which is referred to ground at only one op- amp non-inverting input, so providing a symmetrical output from any non-balanced input whilst having quite superb CMR characteristics. We shall exploit the virtual earth characteristics of the configuration at a later and very important stage in thewil mixer...

Another problem manifests itself in the way that subtle changes can sometimes occur under certain input or routing conditions, wherein feedback paths are created or changed in such a way that whilst the affected amplifiers remain stable under the new conditions, colourations at the LF and HF ends of the spectrum sometimes result. These type of grounding problems are the very devil themselves to first demonstrate —since it requires an infinitely more fertile imagination than mine to envisage all the possible interconnection paths that there might exist — and then to track down and eliminate. Again, it is better to design problems out of the console in the first instance.

Enter The Bucket Brigade

The ideal solution would be to ground every circuit reference point directly to one central earth —the 'star earth' or 'mecca'. Practical considerations in the guise of both the physical size of the multipole connectors required and the size and complexity of the wiring looms which such a system would necessitate mean that we cannot adopt this approach. A half-way house compromise solution to the problem does exist, however, in the form of so-called 'bus' or 'bucket grounding' wherein grounds are grouped together according to the impedance of the circuitry which they feed. In this way, high impedance circuits would share a common earth, as would low impedance. The two connect together only at one central earth point. In this way, the ratio of impedance to ground loss component, Rg, is so large that resultant crosstalk pd's are low enough to ignore. This is somewhat simplistic and exceptions do exist. Any active device with unusual or transient current demands — indicators, switches, amplifier output stages - return directly to the star earth via their own individual path with no other connections to other bucket or bus system grounds along the way. See Figure 6. This method has been used effectively within the power supply unit where all of the grounds on each PCB are grouped together in a star earth arrangement and then connect via one wire to the system star earth. Heavy load current devices —bridge rectifiers, smoothing capacitors and the like are tied to this system star earth via heavy gauge wire. This then means that the reference seen by all of the ground points throughout the system is stable and immovable, and no oscillations, hum loops or instability can occur.

Definite Earths For Mixer Amps

We'll centre the last paragraphs of this discussion on the grounding network around the virtual earth mixer, which, by the very nature of the circuit configuration, amplifies any noise present on the ground line. We will discuss the various quirks and idiosyncracies of the different types of summing or mixing stages which are available at a later stage, but for completeness on this discussion about grounding, the problems which arise in this critical area of the console should be mentioned here and now.

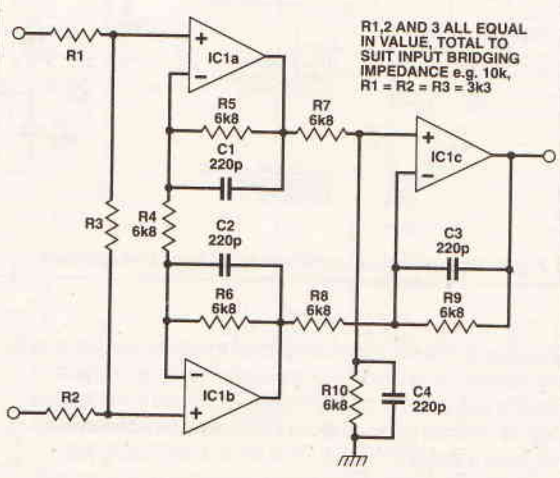


Fig.11a Instrumentation type differential amplifier (with separately buffered inputs)

Refer to Figure 7 which is representative of the main mix bus in a typical desk. It has 48 inputs as we can see and a conventional virtual earth mixing amp.

$$\text{Gain} = \frac{Rf}{R1//R2//R3//......R48}$$

Gain through the system (for an isolated single channel with its fader fully open), is, of course, unity. However, a much neglected factor in the design is that for the system bus, the true electronic gain through the amplifier, in fact, 48 or 33dB. This gain will also amplify any unwanted signals which happen to be present on the earth connection. This ground noise is amplified up by the full gain of the mix-amp and can be of such a high level that it can serve to become the predominant source of noise when compared both to the self-generated noise of the active device used as the virtual earth amp and the Johnson noise of the resistors. Quite conceivably, the ultimate noise performance of this stage is determined by the grounding techniques used in this area and not by the inherent characteristics of the mix amp. It should now be more readily apparent why there were so many separate ground wires of very thick cross sectional area within the PSU and why the only place where the logic and audio grounds connect together is at the star earth point of the whole system.

First Input Stage

Looking back over the cast few months, we've shown some of the various types of Mic Input stage which have cropped up in the front end of many console designs the world over. Latterly, I researched this subject very thoroughly indeed and some other information on Mic Input amplifier design might be of interest before we take the plunge —after presenting the full input stage circuitry — and finally publish the dreaded spec sheet!

We have already justified the use of a transformerless input stage in the preceeding issues of the series, although it has to be said that the transformer input stage was somewhat summarily dismissed —primarily on the grounds of cost —at the commencement of episode two of our unfolding tale. In retrospect, it was perhaps unwise to have done so purely —on the face of it -because transformer costs are comparatively high. In our quest for audio perfection, cost is a relative term and it is perhaps prudent to outline some of the other disadvantages of this type of input whilst expounding the virtues of the op-amp/transistor stage. Furthermore, it is probably a good idea, whilst in this vein of thought, to look more closely at the behaviour at audio frequencies of that most maligned of IC's, the humble op-amp, since the finished console will perhaps house several hundred of the little critters.

We looked in some detail at E_{IN} (Equivalent Input Noise) and the fact that it is the first device which the input signal contacts which determines noise performance from then onwards. This is because of the way in which any noise generated locally in this area of the mixer will tend to swamp noise in succeeding stages since this noise will be at a level lower by an order of magnitude. We also saw that noise in the resistive portion of the microphone is determined by the laws of physics and that thermal or Johnson noise is immovably superimposed upon the signal at this point. Consequently, reducing the noise figure of the amplifier was a matter of calculating the OSR (optimum source resistance) of the active device and then arranging for the connecting source impedance to present an impedance to the amp. which was as close to this OSR as possible. Only in this way would the optimum noise performance be attained from the device in question, be it a transformer/op-amp, op-amp or transistor/op-amp combination.

Recapping, we saw that by a rather unfortunate quirk of the internal architecture of the op-amp, its OSR is much higher than the 200R impedance of a mic. capsule, tending in the main to have a value around the 10k mark.

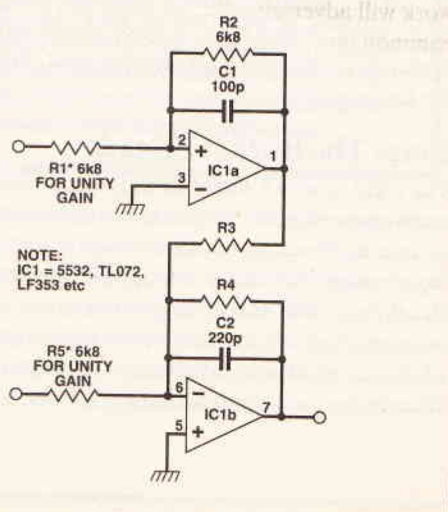


Fig.11b Differential amplifier (not fully floating)

PROJECT

One of the plus points of the transformer coupling arrangement was the way in which the turns ratio (stepping up from input to output) gave us a corresponding 'noiseless' amplification. In that simplistic scenario, we omitted to say that this inherent and unalterable characteristic of the transformer can prove to be more of a blessing than a curse in some situations, the close miking of a drum kit, being an example which immediately springs to mind. This is because any microphone used in this situation will be in close proximity to high level, transient signals whose absolute level may exceed something in the region of +8dBu. It is quite apparent that a seven-fold increase in the level of sounds of this nature will create vast problems for any following amplifier stages — even with unity gain — trying to remain in an unsaturated, unclipped condition since headroom has been sufficiently eroded to drive the amplifier output stage hard against the rails. This is just one of the vast number of factors which have to be considered.

What about 'padding' or attenuating the input signal before it has a chance to clip the amplifier stage? This method can be used and is employed in a vast number of mixing desks. With any attenuators, great care has to be taken with the design since switching resistive elements in and out of a complex capacitive/inductive network — which is what the mic/cable/transformer combination is as far as the amplifier input is concerned — is a dicey business and prone to introducing time and frequency domain changes into an already fragile maintained equilibrium. It also has a subtle but marked effect on the CMRR performance of the input stage. Why? A fiendishly simple but often overlooked effect — it attenuates the differential signal but not the common-mode one so the two are brought inextricably together by the same amount the pad reduces the signal.

To complicate matters further, at high signal levels, the transformer has a tendancy to saturate whilst at low signal levels, the problem of hysteresis (crossover distortion) rears its ugly head and is responsible for the generation of distortion products greater by an order of magnitude than any which succeeding amplification stages should produce. The dynamic range between these two extremes is sadly less than that required of an input stage of this sort since we must expect the mic. to accomodate a largely differing number of levels. So, with a transformer as part of the input stage, some performance compromise must be made in respect of this.

Also, the introduction of any large resistive or capacitive elements into the the immediate transformer network will adversely affect phase linearity, isolation and common mode rejection (CMR). CMR is also affected, of course, by any resistive imbalance in the windings or by co-winding capacitance.

As already said, the mic/cable/transformer combination presents a very complex load to the amplifier input, a network which is further complicated by the fact that half of it -the mic/cable part — can be unplugged. So an amplifier trimmed for good performance and stability when terminated must also behave itself and suppress any tendancy to oscillate when unloaded. This network, therefore, has an appalling phase and frequency response which must be "tamed" and filtered using components which will suppress resonance and iron out kinks in the frequency response respectively. Resonance (gain at specific frequencies) in any stage — unless deliberately introduced, as it might in the EQ section — is something to avoid if at all possible since it robs the amplifier of headroom at the frequency (or frequencies) in question. All of the above dictate that any resistive taming or linearising components must be placed pre-amplifier. Whilst they might suppress oscillations of an unterminated input, they will also worsen noise performance (subsidiary thermal noise from these resistors is now unavoidably introduced) and attenuate all signals, especially low level ones. Figure 8 shows the responses.

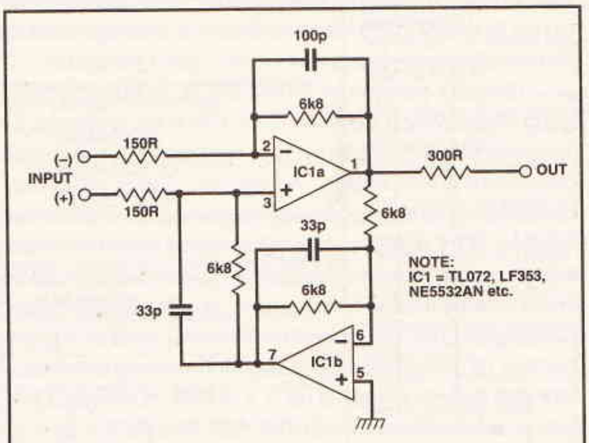


Fig.11c 'Superbal' differential input amplifier

Back To The Feature

So much for the transformer and all of its problems. Now we can at last look to the method used in the AutoMate. Although it is a one-chip amplifier, it comes under the ostentatious heading of 'multi-device input amplifier' since it cascades both transistor and op-amp technology within the chip architecture. Refer to Figure 9. Gain is provided entirely by the first pair of differentially, cross-connected transistors, a combination which provides very good common-mode rejection because there is no connection to ground and only differential-wanted signals are amplified. This is because the reference to amplifier 1 is amplifier 2 and vice versa, each transistor base being tied to an identical in-phase and out-of-phase input signal. Common mode (ie in-phase) signals on both bases cause the references to move up and down in synchrony so that the potential difference developed between the two and the amplifier output is zero (in a perfect situation). If the input is now an out-of-phase, differential signal, normal amplifying operation results since the reference is now a 0V cancellation null point halfway along the gain-determining resistor chain.

The transistor outputs feed into a unity gain differential op-amp stage where all of the surrounding resistor values are kept as low in value as possible (thus reducing thermal noise). Conventionally, the disparity between the impedances presented by the inverting and non-inverting inputs of the op-amp, the non-inverting being defined by resistor values, inverting by circuit feedback — would require optimisation for both nulling and good CMRR (a difficult adjustment to make simultaneously as we'll see in later circuitry). The transistor outputs can be assumed to be effectively zero impedance, so the need for optimisation is eliminated. Although it is not the case with this particular IC, PNP transistors are sometimes used because of their slightly better performance at the bass frequency end of the spectrum.

Using a dedicated pro-audio IC eradicates a great number of circuit design problems in an effortless manner. No transformer is used — we've established why this is desirable over a period of some months! The cost considerations for even a modest transformer are horrendous, and good ones such as the Jensen JE-115K (which is intended for use with the NE5534) are ruinously expensive. Juggling all the problems associated with the transformer in finalizing a design which will work well over a wide range of operating conditions —while the designer strives to define good bandwidth without compromising phase response —is not one of life's great pleasures.

The very process by which the IC is fabricated on wafer ensures the transistors in the first stage are perfectly matched and although discrete bipolar super-matched transistors are available — National Semiconductors' LM194/394 to name one —their price puts them out of bounds. Why struggle with what seems like an infinite number of variables in the quest for a good design when one is readily available at modest cost. It can also be up, running and fully stabilised with the addition of a small number of external components in the shape of capacitors and resistors. Setting up is a matter of nulling a few trim pots but we must ensure that any components external to the IC do not degrade its good performance. This most notable place where damage can be done is in the network which provides the 48V Phantom power for capacitor microphones. CMRR can be ruined by fitting low-tolerance, ill-matched resistors. Good quality metal-film or equivalent types must also be fitted in the gain-determining network or noise performance will worsen.

Next month, we start with a discussion on what is termed 'level architecture' (which is basically the maximizing of overall system performance by choosing amplifier gain such that noise from preceeding stages is swamped whilst headroom is maintained). We then move on to fill in the blank boxes which were labelled, somewhat mysteriously, 'gain setting circuitry'. We look at some of the merits and shortcomings of the ubiquitous operational amplifier before cranking up the pace and looking at equalization in terms of what we should like it to do, what it is capable of doing, how it will sound and finally, how we implement it in electronic terms.

Corrections to Part 2 (May)

On Fig.1 the base of Q201 should connect to the collector of Q202.

In Fig.2 the base of Q101 should also connect to the collector of Q202 (above unlabelled). R202, 203 should be 1k as in the text. C1 and C2 mentioned in the text are in fact C201 and C207. IC201, 202 should be labelled TL071 and Q203, 204 and 207 are MJ11016. Q209, 210 and 212 are MJ11015 (Parts List in Part 3 notes this).

Some confusion seems to have arisen over the component numbering in the PSU circuit diagrams. To clarify resistors, capacitors are numbered in the conventional way 01, 02, 03 etc. Further, the component number is prefixed either 2 or 3, depending on whether it is the Audio or Switching board, such that R201 is resistor 1 on the Audio PSU, C302 is capacitor 2 on the Switching board. Thanks go to 'Confused' of Stowmarket on this.

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FM BUG KIT. New design with PCB embedded coil. Transmits to any FM radio. 9v battery req'd. £5.00 ref 5P158R
FM BUG Built and tested superior 9v operation £14.00 ref 14P3R
COMPOSITE VIDEO KITS. These convert composite video into separate H sync, V sync and video. 12v DC. £8.00 ref 8P39R.
SINCLAIR C5 MOTORS 12v 29A (full load) 3300 rpm 6"x4" 1/4" O/P shaft. New. £20.00 ref 20P22R.
As above but with fitted 4 to 1 inline reduction box (800rpm) and toothed nylon belt drive cog £40.00 ref 40P8R.
SINCLAIR C5 WHEELS 13" or 16" dia including treaded tyre and inner tube. Wheels are black, spoked one piece poly carbonate. 13" wheel £6.00 ref 6P20R, 16" wheel £6.00 ref 6P21R.
ELECTRONIC SPEED CONTROL KIT for c5 motor. PCB and all components to build a speed controller (0-95% of speed). Uses pulse width modulation. £17.00 ref 17P3R.
SOLAR POWERED NICAD CHARGER. Charges 4 AA nicads in 8 hours. Brand new and cased £6.00 ref 6P3R.

12 VOLT BRUSHLESS FAN 4 1/2" square brand new ideal for boat, car, caravan etc. £5.00 ref 5P206.
ACORN DATA RECORDER ALF503 Made for BBC computer but suitable for others. Includes mains adapter, leads and book £15.00 ref 15P43R
VIDEO TAPES. Three hour superior quality tapes made under licence from the famous JVC company. Pack of 5 tapes **New low price £6.00 ref 8P161**
PHILIPS LASER. 2MW HELIUM NEON LASER TUBE. BRAND NEW FULL SPEC £40.00 REF 40P10R. MAINS POWER SUPPLY KIT £20.00 REF 20P33R READY BUILT AND TESTED LASER IN ONE CASE £75.00 REF 75P4R.
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HIGH RESOLUTION 12" AMBER MONITOR 12v 1.5A Hercules compatible (TTL input) new and cased £22.00 ref 22P2R

VGA PAPER WHITE MONO monitors new and cased 240v AC. £59.00 ref 59P4R
25 WATT STEREO AMPLIFIERc. STK043. With the addition of a handful of components you can build a 25 watt amplifier. £4.00 ref 4P69R (Circuit dia included).
BARGAIN NICADS AAA SIZE 200MAH 1.2V PACK OF 10 £4.00 REF 4P92R, PACK OF 100 £30.00 REF 30P16R
FRESNEL MAGNIFYING LENS 83 x 52mm £1.00 ref BD827R.
ALARM TRANSMITTERS. No data avaliable but nicely made complex radio transmitters 9v operation. £4.00 each ref 4P81R.
12V 19A TRANSFORMER. Ex equipment but otherwise ok. Our price £20.00
GX4000 COMPUTERS. Customer returned games machines complete with plug in game, joysticks and power supply. Retail price is almost £100. Ours is £12.00 ref B12P1
ULTRASONIC ALARM SYSTEM. Once again in stock these units consist of a detector that plugs into a 13A socket in the area to protect. The receiver plugs into a 13A socket anywhere else on the same supply. Ideal for protecting garages, sheds etc. Complete system £25.00 ref B25P1 additional detectors £11.00 ref B11P1
IBM XT KEYBOARDS. Brand new 86 key keyboards £5.00 ref 5P612
IBM AT KEYBOARDS Brand new 86 key keyboards £15.00 ref 15P612
386 MOTHER BOARDS. Customer returned units without a cpu fitted. £22.00 ref A22P1

BSB SATELLITE SYSTEMS

BRAND NEW

REMOTE CONTROL

£49.00 REF F49P1

286 MOTHER BOARDS. Brand new but customer returns so may need attention. Complete with technical manual £20.00 ref A20P2
286 MOTHER BOARDS. Brand new and tested complete with technical manual. £49.00 ref A49P1
UNIVERSAL BATTERY CHARGER. Takes AA's, C's, D's and PP3 nicads. Holds up to 5 batteries at once. New and cased, mains operated. £6.00 ref 6P36R.
IN CAR POWER SUPPLY. Plugs into cigar socket and gives 3,4,5,6,7.5,9, and 12v outputs at 800mA. Complete with universal spider plug. £5.00 ref 5P167R.
RESISTOR PACK. 10 x 50 values (500 resistors) all 1/4 watt 2% metal film. £5.00 ref 5P170R.

MIRACOM WS4000 MODEMS

V21/23

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AUTODIAL/AUTOANSWER

FULL SOFTWARE CONTROL

TONE AND PULSE DIALLING

£29

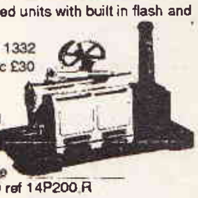
IBM PRINTER LEAD. (D25 to centronics plug) 2 metre parallel. £5.00 ref 5P186R.
COPPER CLAD STRIP BOARD 17" x 4" of .1" pitch "vero" board. £4.00 a sheet ref 4P62R or 2 sheets for £7.00 ref 7P22R.
STRIP BOARD CUTTING TOOL. £2.00 ref 2P352R.
50 METRES OF MAINS CABLE £3.00 2 core black precut in convenient 2 m lengths. Ideal for repairs and projects. ref 3P91R
4 CORE SCREENED AUDIO CABLE 24 METRES £2.00 Precut into convenient 1.2 m lengths. Ref 2P365R
TWEETERS 2 1/4" DIA 8 ohm mounted on a smart metal plate for easy fixing £2.00 ref 2P366R
COMPUTER MICE Originally made for Future PC's but can be adapted for other machines. Swiss made £8.00 ref 8P57R. Atari ST conversion kit £2.00 ref 2P362R.
6 1/2" 20 WATT SPEAKER Built in tweeter 4 ohm £5.00 ref 5P205R
WINDUP SOLAR POWERED RADIO! FM/AM radio takes rechargeable batteries complete with hand charger and solar panel 14P200R

PC STYLE POWER SUPPLY Made by AZTEC 110v or 240v input +5@15A,+12@5A,-12@.5A,-5@.3A Fully cased with fan, on/off switch, IEC inlet and standard PC flyleads. £15.00 ref F15P4
ALARM PIR SENSORS Standard 12v alarm type sensor will interface to most alarm panels. £16.00 ref 16P200
ALARM PANELS 2 zone cased keypad entry, entry exit time delay

etc. £18.00 ref 18P200
MODEMS FOR THREE POUNDS!! Fully cased UK modems designed for dial up system (PSTN) no data or info but only £3.00 ref 3P145R
TELEPHONE HANDSETS Bargain pack of 10 brand new handsets with mic and speaker only £3.00 ref 3P146R
BARGAIN STRIPPERS Computer keyboards. Loads of switches and components excellent value at £1.00 ref CD40R
DATA RECORDERS Customer returned mains battery units built in mic ideal for Computer or general purpose audio use. Price is £4.00 ref 4P100R
SPECTRUM JOYSTICK INTERFACE Plugs into 48K Spectrum to provide a standard Atari type joystick port. Our price £4.00 ref 4P101R
ATARI JOYSTICKS Ok for use with the above interface, our price £4.00 ref 4P102R
BENCH POWER SUPPLIES Superbly made fully cased (metal) giving 12v at 2A plus a 6V supply. Fused and short circuit protected. For sale at less than the cost of the case! Our price is £4.00 ref 4P103R
SPEAKER WIRE Brown twin core insulated cable 100 feet for £2.00 REF 2P79R
MAINS FANS Brand new 5" x 3" complete with mounting plate quite powerfull and quite. Our price £1.00 ref CD41R
DISC DRIVES Customer returned units mixed capacities (up to 1.44M) We have not sorted these so you just get the next one on the shelf. Price is only £7.00 ref 7P1R (worth it even as a stripper)
HEX KEYBOARDS Brand new units approx 5" x 3" only £1.00 each ref CD42R
PROJECT BOX 51/2" x 31/2" x 1" black ABS with screw on lid. £1.00 ref CD43R
SCART TO SCART LEADS Bargain price leads at 2 for £3.00 ref 3P147R
SCART TO D TYPE LEADS Standard Scart on one end, Hi density D type on the other. Pack of ten leads only £7.00 ref 7P2R
OZONE FRIENDLY LATEX 250ml bottle of liquid rubber sets in 2 hours. Ideal for mounting PCB's fixing wires etc. £2.00 each ref 2P379R
QUICK SHOTS Standard Atari compatible hand controller (same as joysticks) our price is 2 for £2.00 ref 2P380R
VIEWDATA SYSTEMS Brand new units made by TANDATA complete with 1200/75 built in modem infra red remote controlled qwerty keyboard BT appproved Prestel compatible, Centronics printer port RGB colour and composite output (works with ordinary television) complete with power supply and fully cased. Our price is only £20.00 ref 20P1R
AC STEPDOWN CONVERTOR Cased units that convert 240v to 110v 3" x 2" with mains input lead and 2 pin American output socket (suitable for resistive loads only) our price £2.00 ref 2P381R
SPECTRUM +2 LIGHT GUN PACK complete with software and instructions £8.00 ref 8P58R/2
CURLY CABLE Extends from 8" to 6 feet! D connector on one end, spade connectors on the other ideal for joysticks etc (6 core) £1.00 each ref CD44R
COMPUTER JOYSTICK BARGAIN Pack of 2 joysticks only £2.00 ref 2P382R
BUGGING TAPE RECORDER Small hand held cassette recorders that only operate when there is sound then turn off 6 seconds after so you could leave it in a room all day and just record any thing that was said. Price is £20.00 ref 20P3R
IEC MAINS LEADS Complete with 13A plug our price is only £3.00 for TWO! ref 3P148R
NEW SOLAR ENERGY KIT Contains 8 solar cells, motor, tools, fan etc plus educational booklet. Ideal for the budding enthusiast! Price is £12.00 ref 12P2R

286 AT PC
286 MOTHER BOARD WITH 640K RAM FULL SIZE METAL CASE, TECHNICAL MANUAL, KEYBOARD AND POWER SUPPLY £139 REF 139P1 (no i/o cards or drives included) **Some metal work req'd phone for details.**

35MM CAMERAS Customer returned units with built in flash and 28mm lens **2 for £8.00 ref 8P200**
STEAM ENGINE Standard Mamod 1332 engine complete with boiler piston etc £30 ref 30P200



TALKING CLOCK LCD display, alarm, battery operated. Clock will announce the time at the push of a button and when the alarm is due. The alarm is switchable from voice to a cock crowing! £14.00 ref 14P200.R
HANDHELD TONE DIALLERS Small units that are designed to hold over the mouth piece of a telephone to send MF dialling tones. Ideal for the remote control of answer machines. £5.00 ref 5P209R
COMMODORE 64 MICRODRIVE SYSTEM Complete cased brand new drives with cartridge and software 10 times faster than tape machines works with any Commodore 64 setup. The orginal price for these was £49.00 but we can offer them to you at only £25.00! Ref 25P1R
ATARI 2600 GAMES COMPUTER Brand new with joystick and 32 game cartridge (plugs into TV) £29.00 ref F29P1 also some with 1 game at £19.00 ref F19P2.
BEER PUMPS Mains operated with fluid detector and electronic timer standard connections. Ex equipment. £18.00 ref F18P1
90 WATT MAINS MOTORS Ex equipment but ok (as fitted to above pump) Good general pupose unit £9.00 ref F9P1
HI FI SPEAKER BARGAIN Originally made for TV sets they consist of a 4" 10 watt4R speaker and a 2" 140R tweeter. If you want two of each plus 2 of our crossovers you can have the lot for £5.00 ref F5P2.
VIDEO TAPES E180 FIFTY TAPES FOR £70.00 REF F70P1
360K 5 1/4" Brand new drives white front. £20.00 Ref F20P1

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PROJECT INDEX 1972-1992

INDEX

GAMES

LIGHTING

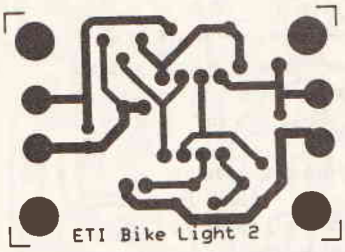
TEST EQUIPMENT

INDEX

This index, presented in four parts (April-July 1992), coverrs 20 years to April 1992. Projects from this date to the present time have not been included.

PCB Foils

PCB foils patterns presented here are intended as a guide only. They can be used as a template when using tape and transfer for the creation of a foil.



Improved LED read bike light foil

Pond Level Controller May '92
Figure 2 The central hole is 28mm diameter. Figure 3, unmarked dimension should be 30mm. Note 4 refers to slot in sensor probe. In Figure 4 D1-4 are shown the wrong way round. Also C5 should be connected to the lower two holes of the three.
In Figure 6, C3 is missing. It should be in series with R2 across the solenoid valve.

Chip Stereo Amplifier June '92
In Figure 1 C11,12 should be labelled 100n. R9 should be 1R0 as in parts list. R4 (1k0) should be inserted in series in the negative rail between Q2 and IC1a. This is shown on the overlay.
In the parts list, C11,12,14,15,108 should be inserted after C1,2,5,8' (100n). Delete C14,15 under 10µ catagory.

Frequency Meter Range Extender June 92
Capacitor C1 should be 10u not 100n, positive to R2. C2 should be 22u not 3n3, positive to R7. There should be a 100u (C6) electrolytic connected in series with R5, positive uppermost, negative to ground.

Xenon Flash Trigger June '92

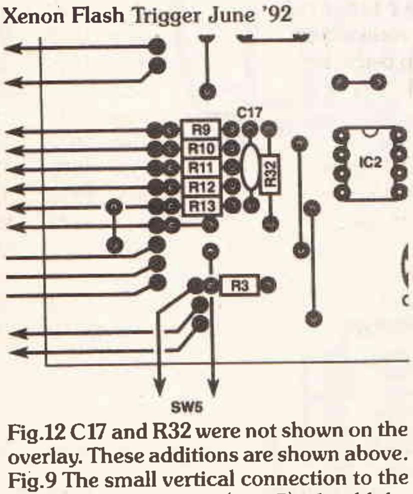
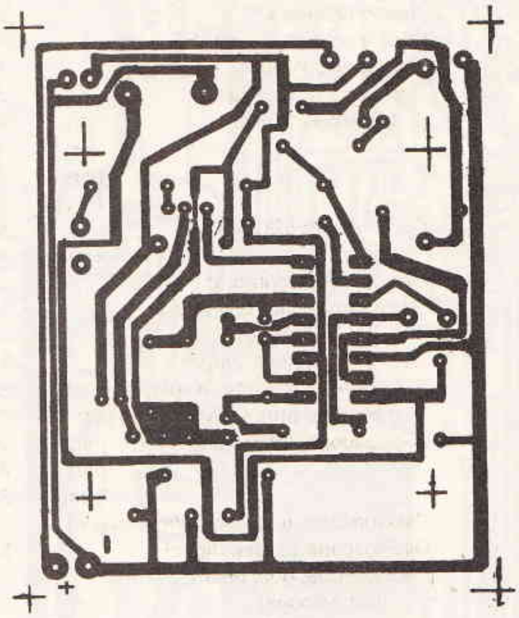
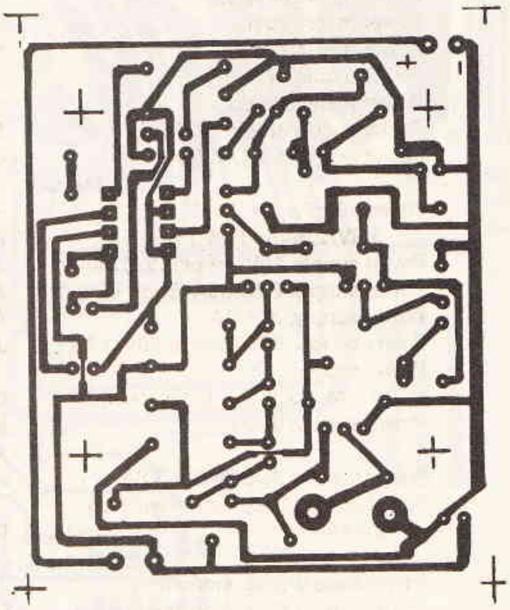


Fig.12 C17 and R32 were not shown on the overlay. These additions are shown above. Fig.9 The small vertical connection to the lower right of IC4c (pin 5) should be deleted ie SW3 is connected to pin 6 IC4c only.

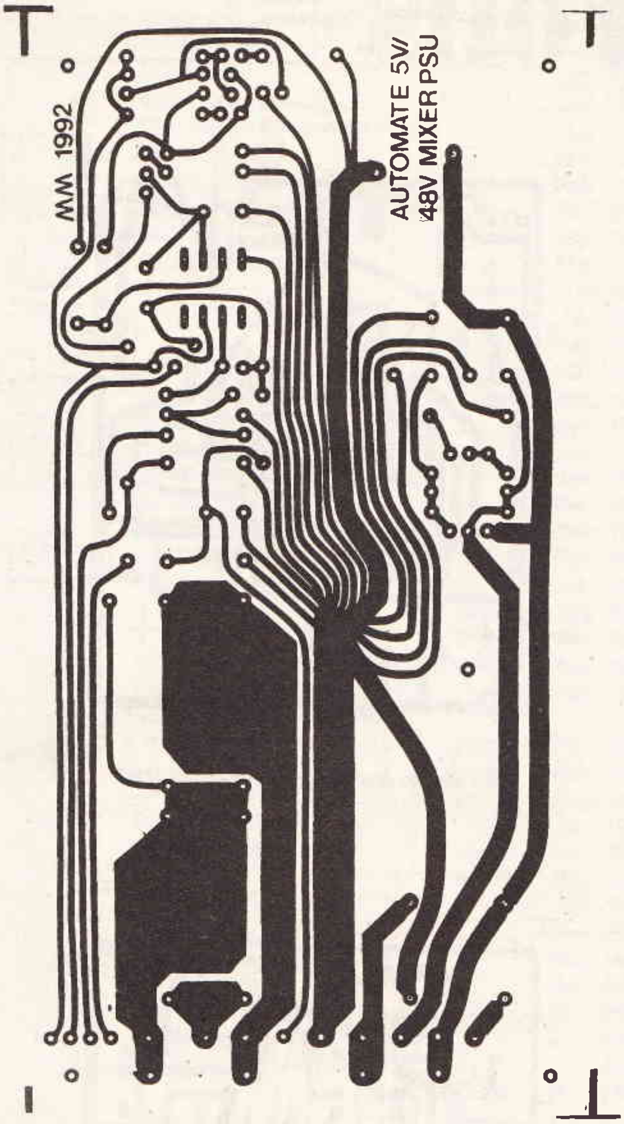


Ultrasonic Audio sender (transmitter)

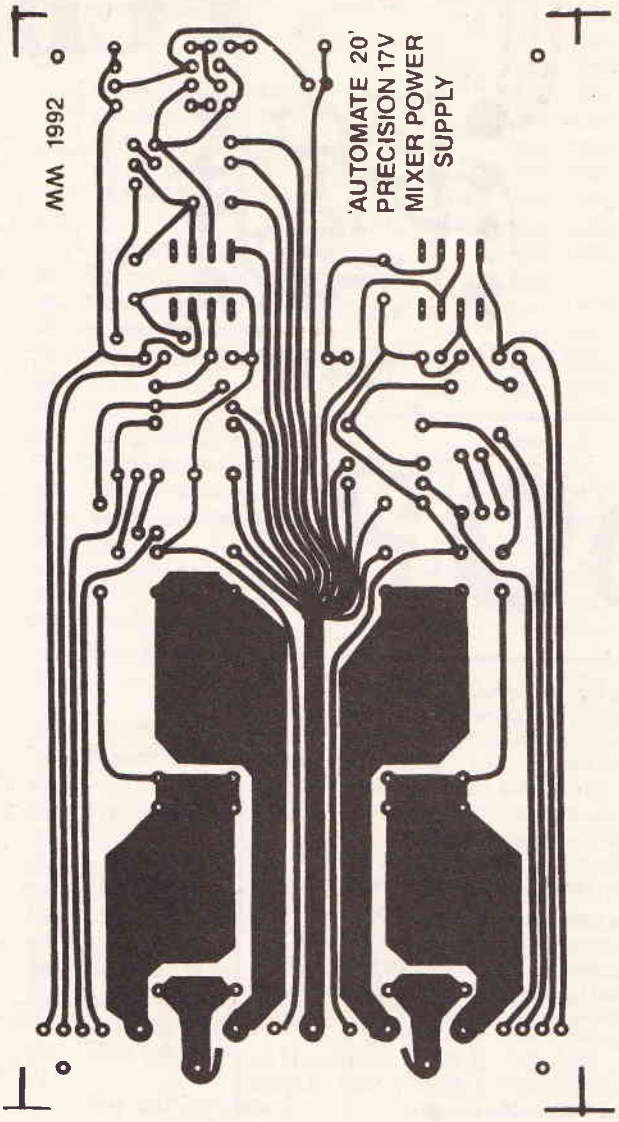


Ultrasonic Audio sender (receiver)

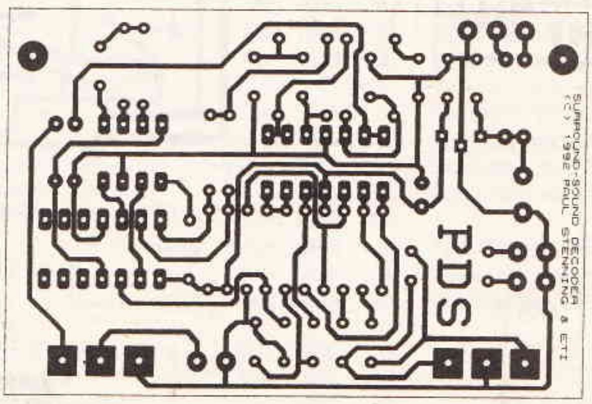
Mini Baby bug monitor



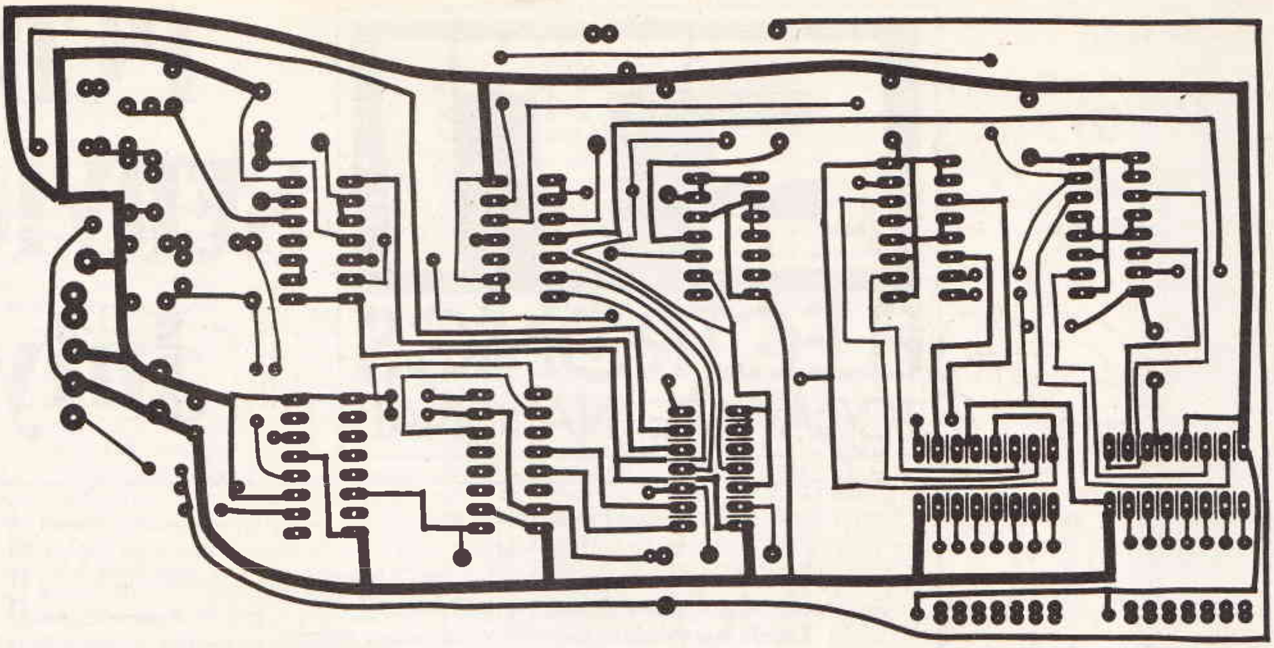
AutoMate 5V/48V Mixer power supply



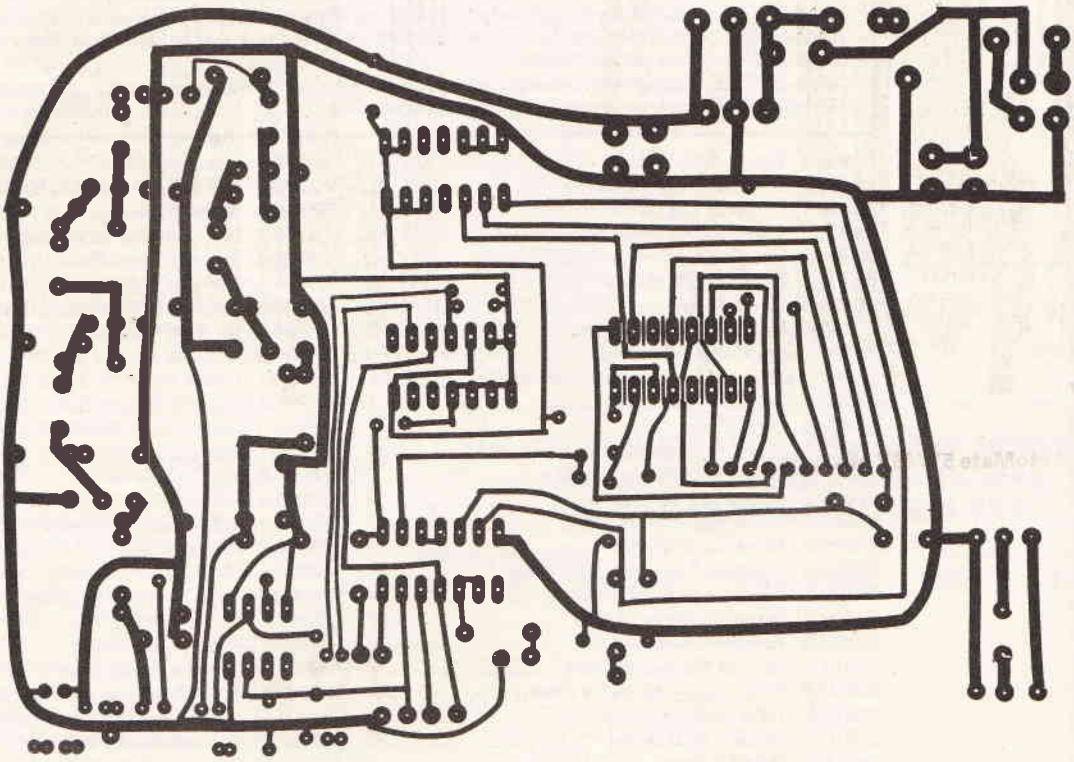
AutoMate Precision 17V power supply



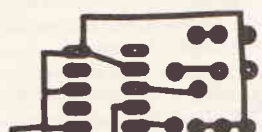
Surround Sound decoder foil



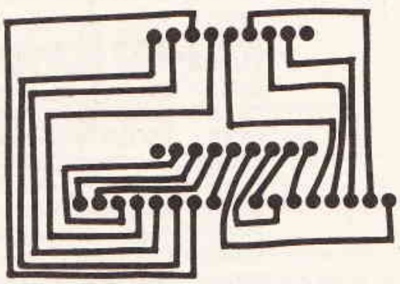
Camera Add-on Divider/Counter/Decoder board



Camera Add-on Sound/Infra-red trigger board



Camera Add-on Infra-red
emitter board



Camera Add-on — Display

ELECTRONICS TODAY INTERNATIONAL

PCB SERVICE July

E9207-1	Improved Rear Bike Lamp	D
E9207-2	Mini Baby Bug Monitor	C
E9207-3	Ultra Sonic Audio Sender (2 boards)	H
E9207-4	Camera Add-on unit (4 boards)	D
E9207-5	AutoMate 5V/48V Mixer power supply	J
E9207-6	AutoMate Precision 17V power supply	J
E9207-FC	Surround Sound Decoder	F

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

Use the form or a photocopy for your order. Please fill our 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.

Terms are strictly payment with order. We cannot accept official orders but we can supply a proforma invoice if required. Such orders will not be processed until payment is received.

E8805-3	Bicycle Speedometer	F
E8805-4	Dynamic Noise Reduction	E
E8806-1	Universal Digital Panel Meter	L
E8806-2	Universal Bar Graph Panel Meter	K
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
E8807-6	Breath Rate Display Board	F
E8808-1	Breath Rate Main Board	H
E8808-2	Breath Rate Switch Board	C
E8808-3	Telephone Recorder	D
E8808-4	Analogue Computer Main Board (2 bds)	M
E8809-1	Spectrum EPROM Emulator	M
E8809-2	Frequency Meter (2 bds)	P
E8809-3	Travellers' Aerial Amp	E
E8810-1	Gerrada Marweh Bikebell	E
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
E8812-6	Burglar Buster Alarm Board	C
E8812-7	Burglar Buster Bleeper Board	C
E8901-1	EPROM Programmer mother board	M
E8901-2	Variat-Ion updated Main Board	H
E8901-3	Variat-Ion Emitter Board	E
E8901-4	In-car Power Supply	C
E8901-5	Granny's Hearing Booster	E
E8902-1	Compressor/Limiter/Gate	L
E8902-2	Ultrasonic Horn	D
E8902-3	Stepper Motor Driver Board	L
E8902-4	Quest-Ion (2bds)	K
E8903-1	Intelligent Plotter Solenoid Board	H
E8903-2	MIDI Programmer	L
E8903-3	Balanced Disc Input Stage	F
E8903-4	Digitally Tuned Radio	G
E8904-1	Camera Trigger	E
E8904-3	Intelligent Plotter Main Board	O
E8904-4	Kinetotie Tie Board	N
E8904-5	Kinetotie Control Board	E
E8905-1	Guitar Tuner	H
E8905-2	Camera Trigger Ultrasonics (2 boards)	F
E8905-3	Bench Power Supply (2 boards)	H
E8906-1	PC edge connector	F
E8906-2	MIDI converter CPU	N
E8906-3	MIDI converter keyboard	N
E8906-4	MIDI converter control	M
E8906-5	AF signal generator	G
E8906-6	Mini bleeper	C
E8906-7	Caravan heater controller	G
E8907-1	MIDI Patch Bay	G
E8907-2	Priority Quiz Switch	E
E8907-3	Camera Trigger Infra-reds (2 boards)	G
E8907-4	Aerial Amplifier main board	E
E8907-5	Aerial Amplifier power supply	E
E8908-1	Intercom master station	L
E8908-2	Intercom slave station	F
E8908-3	Intercom power mixer	E
E8908-4	Digital joystick-to-mouse conversion	H
E8909-1	Twin Loop Metal Locator	H
E8909-2	Trembler movement detector	D
E8909-3	Field power supply (spec 3)	C
E8909-4	Micro monitors active filter	F
E8909-5	Chronoscope auto-reset	C
E8910-1	Multimeter	H
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

E8912-5	Digital Noise Generator	K
E9001-1	20 metre Receiver	J
E9001-2	Wavemaker FG	L
E9001-3	Motorcycle Intercom	F
E9001-4	Low Voltage Alarm	C
E9002-1	EPROM Emulator	N
E9002-2	Superscope Mother Board	M
E9002-3	Superscope CRT Driver Board	K
E9002-4	Superscope Timebase Board	K
E9003-1	Superscope Y1 input board	J
E9003-2	Superscope Y2 input board	J
E9003-3	Superscope switch generator	E
E9003-4	Business power amp board	L
E9003-5	Business power supply board	J
E9003-6	Business pre-amplifier board	L
E9003-7	Water hole	G
E9003-8	Super Siren	D
E9003-9	Val's badge	F
E9004-1	Bass Amplifier DC Protection	F
E9004-2	Bass Amplifier Graphic Equaliser	L
E9004-3	Bass Amplifier Micro	N
E9004-4	Quad Power Supply	O
E9005-1	Business Display	O
E9005-2	Phone Lock and Logger	F
E9006-1	Dark Room Timer	G
E9006-2	Telephone Extension Bell	C
E9006-3	Telephone External Bell	D
E9006-4	Fecko Box	G
E9006-5	Bug Spotter	E
E9007-1	Guitar Practice Amp	G
E9007-2	Digital Frequency Meter	M
E9007-3	Footstep Alarm	E
E9007-4	Transistor Tester	C
E9007-5	Decision Maker	J
E9008-1	AC Millivoltmeter	K
E9008-2	Temperature Controller	N
E9008-3	FM Generator	L
E9009-1	Slide Projector Controller	E
E9009-2	Ultimate Diode Tester	D
E9009-3	The Entertainer	G
E9010-1	Component Tester	F
E9010-2	Active Contact Pickup	E
E9010-3	R4X Longwave Receiver	C
E9011-1	The Autocue (2 boards, 1 double sided)	N
E9011-2	Infra-lock transmitter (2 boards)	K
E9011-3	Infra-lock receiver	H
E9011-4	Four-track cassette recorder (record/playback one channel)	F
E9011-5	Four-track cassette recorder (Bias/erase oscillator board	K
E9012-1	Infra Switch	F
E9101-1	Remote Control — Main Board	J
E9101-2	Remote Control — Display Board	H
E9101-3	Remote Control Timeswitch — Transmit board	E
E9101-4	SBC Micro-Controller Board	F
E9101-5	SBC Practice Interface Board	F
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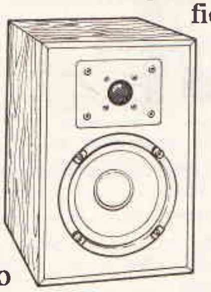

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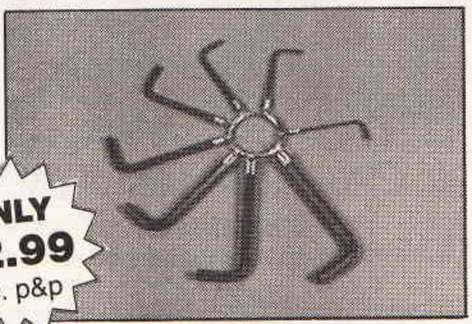

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NEXT MONTH

Amongst the multitude of projects lined up for you next month we include a novel design for a dynamic noise limiter, a cost effective way to turn a plane keyboard into a MIDI activated synthesiser, a smart intercom system, and a simple and incredibly thin DIY television aerial that could even dissappear behind the wallpaper. Not forgetting we give a complete PCB away on the cover of ETI every month. Next month we present an auto controlled battery charger to add an element of safety to the charging process of your car battery. Our features include more on the latest ideas for digital TV, a beginners guide to using waveguides and Ray Marston continues his test gear series looking at Multi-meter circuits.

These are just some of the things coming your way in our August issue. Pick up a copy from your newsagent on Friday 3rd July.

The above articles are in preparation but circumstances may prevent publication

LAST MONTH

Articles that appeared in the June issue were:

Rear LED Bike Light
Scanner for Sine wave Oscillator
Chip stereo Amplifier
Phase Locked Loop circuits
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