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No. 85

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ELECTRONICS

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How to Receive Weather Satellite Images on your PC

All About Choosing & Using LEDs

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How to Store Speech Electronically

Build a Superb Hi-Fi Valve Preamplifier

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JANUARY 1995
VOL 14. No. 85

IN THIS ISSUE...

PROJECTS *FOR YOU TO BUILD!*

FEATURES *ESSENTIAL READING!*

REGULARS *NOT TO BE MISSED!*

ABOUT THIS ISSUE . . .

Hello and welcome to this month's issue of *Electronics!*

Valve audio fans will, I am sure, be pleased to see the Newton modular Hi-Fi valve preamplifier in this issue – it follows in the footsteps of the popular Millennium 4-20 Hi-Fi valve power amplifier published a year ago. The Newton preamplifier comprises three main modules: a low-noise power supply; a phono preamplifier and line driver; and a tone control. The first two of these modules are presented this month and the final one next month. The Newton is the ideal companion for the Millennium, but it need not be confined as a front end for valve power amps, it is equally suited to driving 'modern' transistor power amps.

Almost nine years ago, the MapSat weather satellite receiving system was published in *Electronics*, since then technology has moved on in leaps and bounds. The MapSat2 satellite receiving system was recently unveiled in the 1994/5 Maplin Catalogue, and in this issue the receiver, computer interface and software are examined in detail. I am sure that there will be as much, if not more, interest in MapSat2 as there was for the original system in 1986. Computer technology has, of course, also developed as well so the capabilities of displaying, storing and manipulating images are considerably enhanced. The original system used a BBC or Amstrad computer to display the images, whereas MapSat2 makes use of an IBM compatible PC. Users of the original MapSat system will be pleased to learn that their existing system can be updated with the addition of the MapSat2 computer interface unit and software (and of course an IBM compatible PC if you don't already have one).

In the November issue of *Electronics*, the introduction of Caller Line Identification (CLI) on the BT telephone network was discussed. It has since come to light that there are a few teething problems and some difference of opinion between telecomms operators. For those of you not already aware, on the 5th November 1994 BT introduced CLI on their telephone network. The CLI system conveys the calling party's telephone number over the telephone network so that it is displayed on the called party's telephone equipment (but only if the called party has suitable equipment). From 22nd November 1994 customers on the BT network could find out the telephone number of the person who last called them (free) by dialling 1471 (call return). To prevent your number from being passed over the telephone network, you can dial 141 (call block) before the number of the number you are calling. It has transpired that Mercury customers may loose out on long distance call savings if the call block number is used. Apparently it can confuse the call routing apparatus, so instead of routing the call via the Mercury network, it will be routed via the BT network. Mercury are suggesting that their customers apply to BT for a line block, so that their CLI is never passed over the telephone network. Furthermore, Mercury have announced, that until further notice, all calls routed via Mercury will not convey the CLI. Additionally, not all parts of the BT network are up and running with CLI yet, depending on whether you are connected to a digital exchange or not! BT customers with queries on CLI, call block and call return, can call (free) Tel: 0800 801 471 or Tel: 0800 800 181, applications for a line block can be made by calling (free) Tel: 150. Mercury customers with queries can call (free) Tel: 0500 500 193. I'll keep you updated with further developments.

So until next month, from everyone here at *Electronics*, enjoy this issue!

Exclusive Subscribers' Club Special Offer

On offer this month, to subscribers only, is a selection of four specially selected items: a versatile 3-in-1 Multi-purpose Lantern, a powerful 12V Car Halogen Spot Light, a 'Mugger Buster' Personal Attack Alarm & Torch and a comprehensive 7-piece Starter Tool Kit & Tool Roll. There's a total saving of £8.50 on these items, based on their normal price. If you are a subscriber, full details of how to order these items are included on the special offer leaflet in this issue – if the leaflet is missing, contact Customer Services, Tel: (01702) 552911. If you are not a subscriber and would like to take advantage of future special offers and other benefits of subscribing, turn to page 37 of this issue to find out more or Tel: (01702) 554161.

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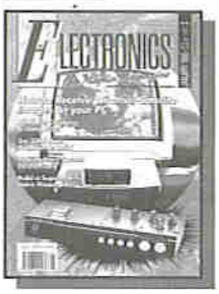

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Project Ratings

Projects presented in this issue are rated on a 1 to 5 for ease or difficulty of construction to help you decide whether it is within your construction capabilities before you undertake the project. The ratings are as follows:

1. Simple to build and understand and suitable for absolute beginners. Basic of tools required (e.g., soldering iron, side cutters, pliers, wire strippers and screwdriver). Test gear not required and no setting-up needed.
2. Easy to build, but not suitable for absolute beginners. Some test gear (e.g., multimeter) may be required, and may also need setting-up or testing.
3. Average. Some skill in construction or more extensive setting-up required.
4. Advanced. Fairly high level of skill in construction, specialised test gear or setting-up may be required.
5. Complex. High level of skill in construction, specialised test gear may be required. Construction may involve complex wiring. Recommended for skilled constructors only.

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Kits, components and products stocked by Maplin can be easily obtained in a number of ways:

Visit your local Maplin store, where you will find a wide range of electronic products.

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Prices of products and services available from Maplin, shown in this issue, include VAT at 17·5% (except items marked NV which are rated at 0%) and are valid between 2nd December 1994 and 28th February 1995 errors and omissions excluded. Prices shown do not include mail order postage and handling charges, which are levied at the current rates indicated on the Order Coupon in this issue.

Technical Enquiries

If you have a technical enquiry relating to Maplin projects, components and products featured in *Electronics*, the Customer Technical Services Department may be able to help. You can obtain help in several ways; over the phone, Tel: (01702) 556001 between 9.00am and 5.30pm Monday to Friday, except public holidays; by sending a facsimile, Fax: (01702) 553935; or by writing to: Customer Technical Services, Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Don't forget to include a stamped self-addressed envelope if you want a written reply! Customer Technical Services are unable to answer enquiries relating to third-party products or components which are not stocked by Maplin.

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If you get completely stuck with your project and you are unable to get it working, take advantage of the Maplin 'Get You Working' Service. This service is available for all Maplin kits and projects with the exception of: 'Data Files'; projects not built on Maplin ready etched PCBs; projects built with the majority of components not supplied by Maplin; Circuit Maker ideas; Mini Circuits or other similar 'building block' and 'application' circuits. To take advantage of the service, return the complete kit to: Returns Department, Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Enclose a cheque or Postal Order based on the price of the kit as shown in the table below (minimum £17). If the fault is due to any error on our part, the project will be repaired free of charge. If the fault is due to any error on your part, you will be charged the standard servicing cost plus parts.

Kit Retail Price	Standard Servicing Cost
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Readers Letters

We very much regret that the editorial team are unable to answer technical queries of any kind, however, we are very pleased to receive your comments about *Electronics* and suggestions for projects, features, series, etc. Due to the sheer volume of letters received, we are unfortunately unable to reply to every letter, however, every letter is read — your time and opinion is greatly appreciated. Letters of particular interest and significance may be published at the Editors discretion. Any correspondence not intended for publication must be clearly marked as such.

Write to: The Editor, Electronics – The Maplin Magazine, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

TECHNOLOGY WATCH!

with Keith Brindley

A couple of months ago, I asked readers who were connected to the Internet to e-mail me with details about their facilities and what use they make of them. I've got the results of this survey this month and they make interesting reading.

Readers are roughly split equally three-ways between education (mostly universities, but a handful of schools too), business, and private users. This was an unexpected result for me personally, because I thought that the fairly high access prices for Internet services (at least £10 a month for subscriptions, and telephone call charges on top) would put a lot of individuals off using Internet. I'd always reckoned that people would generally tend to use an office computer (at work or university, say) for Internet access. And while they obviously do where that facility exists, it doesn't seem to stop private individuals (without the office facility) from joining up. There again, you've got to remember the readership of *Electronics – The Maplin Magazine* is consumer-based. The magazine is not necessarily read by educational or business people alone, and instead is aimed at private individuals.

All readers use their Internet facility for e-mail. Er, obvious really – they all e-mailed their responses to me! Over 90% of all respondents also use proper Internet access for facilities such as FTP, Gopher, World Wide Web and so on. Naturally, of course, if you sign up for Internet access with any of the Internet access providers, there seems little point in not using the Internet to the full, nevertheless I was interested in the percentage of people who *do* actually use the Internet for its full worth. Again, this figure may be somewhat different to the figures which may be obtained from readers of another type of magazine. Readers of *Electronics – The Maplin Magazine* are technically minded (I think it is a safe bet to assume – that you wouldn't be reading this if you weren't), so a similar survey of readers of, say, *Bird Spotters' World* wouldn't have quite the computer proficiency and so might not make the same use of a service as the Internet. (OK, bird spotters of the world, unite, gird your loins, and tell me otherwise!)

As to times spent using the Internet and its facilities; most respondents (around 50%) use it for less than 5 hours a month. Around 33% use it for less than 10 hours a month. The remainder (around 17% if my maths is right) use it for more than 10 hours a month. That may be an interesting result if you're thinking about signing up to the Internet, and have a rough idea about how long you think you'll be on-line. In other words, are you average, or above average? Don't e-mail me on that one!

Finally, with tongue firmly in cheek, I'd like to refer to a couple of readers who replied to the survey and slapped my wrists (metaphorically speaking) with *their* tongues in their cheeks (*mixed* metaphorically speaking!) about my passing remark in the November issue about the version of FirstClass – the graphically-interfaced e-mail and bulletin board system – which was available for (and I quote myself expecting no further reprimand) "those unfortunates who use Windows". Yes indeed, I *did* say that. Dreadful isn't it? But there again you have to remember that once upon a time (and it really seems like a fairy story to me) I *was* one of those unfortunates – so I write from personal experience.

Now, wait until I get my tongue out of my cheek . . . Ah, that's better. Yes. Point taken. I didn't mean to alienate any of our readers who make use of a particular type of computer. It was intended as fun and taken as such (I hope) by all who read it. Users of the differing computer platforms inevitably poke fun at other platforms, usually because you've got to be able to justify (to yourself if to nobody else) why you bought that platform in the first place. In most terms, each computing platform is capable of doing most tasks expected of it. And as long as your computer does what you want from it, then that is probably the right computer for you. Topic closed, but thanks to the reader who also said that what he did on the Internet wasn't so much net-surfing, more like "pottering in a virtual allotment". Nice one.

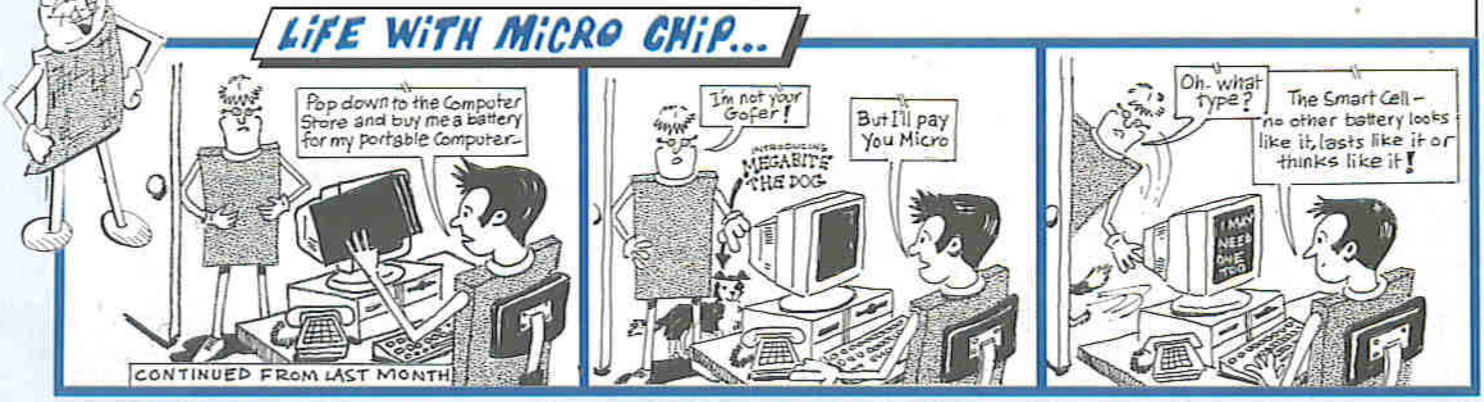
If you would like to drop me a line about anything relating to *Technology Watch* you can e-mail it to **Tech_Watch@maplin.demon.co.uk** or send it snail mail to **Technology Watch, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex, SS6 8LR.** I cannot guarantee a personal reply to every e-mail or letter, but I'll follow up anything of particular interest.

Smart cell/soft sell

News of evolving standards concerning batteries, particularly those used in portable computers suggests that over the next couple of years, batteries with some limited form of intelligence will come onto the market. These will allow users, their notebook computers, and the batteries themselves, to monitor the battery's state of charge, and automatically optimise system use for greatest performance. Previously, I suspect, battery manufacturers were happy to provide batteries for computer manufacturers to use within portable computers, but leave the onus on the computer manufacturers to get their computer's power consumption down to respectable limits to give users a battery life of a reasonable period. This in turn, led computer manufacturers to press the integrated circuit manufacturers for ICs which consume less power. Both integrated circuit and computer manufacturers have, of course, responded with the result that modern notebook computers can run for significantly longer periods than they used to do just a couple of years ago.

That's not to say that battery manufacturers have been sitting around doing nothing, on the other hand. (how I just *lurv* mixing my metaphors). Duracell and Energizer (you may have heard of them) have both been forging alliances with integrated circuit manufacturers (Intel in the case of Duracell, National Semiconductor for Energizer) to design batteries complete with integral controlling circuits. While it'll be a little while until these batteries are for sale, most portable computer users will be looking forward to them, no doubt.

The opinions expressed by the author are not necessarily those of the publisher or the editor.



NEWTON STEREO VALVE PREAMPLIFIER

PART:1

RIAA Phono Module

Design by Mike Holmes and John Mosely
Text by Mike Holmes

It was only logical that the 'Millennium 4-20' 20W power amplifier should eventually be followed by an audio preamplifier to partner it. It should be noted, however, that the 'Newton' need not be restricted to serving the 'Millennium' alone, and it is easily capable of filling in as the front end for other power amplifiers, valve types or otherwise.

In addition, it is often necessary for a stereo preamplifier to cater for many other items of equipment to be connected to it, and simultaneously be able to provide line level outputs to tape recorders and receive other signal sources, such as from a tuner, CD, etc., even for off-tape monitoring, via multi-way selector switches. This versatility can extend to providing a number of auxiliary mains outlets for the other equipment, thus saving on the number of multiple plugblocks required.

How many of these facilities you feel you need is entirely up to you, the constructor, hence, of the three modules in total, only the power supply unit is described in any great detail as to its construction, to ensure that it is safe to use according to mains power and earthing regulations.

Proponents of 'minimalism' who will just want to play their records through valves won't want all this paraphernalia (even less so the tone control module, or so I am assured). If, however, you are the sort whose idea of a decent preamplifier unit is a glorified switch-box – for the best of all reasons of course, that is, that you have lots of other sound sources to plug into it – there still has to be some sort of electronics at the heart of it.

System Overview

The Phono Module, along with the Tone Control Module, provides the basic electronics. It is difficult (and, in my opinion, not right) for us to dictate precisely how you should build a 'good' stereo preamplifier. Only you will know what is 'good' for you. Only you know how many and what sort of switches you want, what style of knobs, etc., and the size and shape of the thing. Therefore we have tried, as far as

FEATURES

- Simple PCB construction
- Compact stereo module
- Versatile connection options
- Onboard low-impedance line driver
- Passive RIAA equalisation
- High output
- Wide dynamic range

KIT AVAILABLE (LT76H)
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4
PROJECT RATING

possible, to make the modules as universal as is practicable; in fact you can look on them as virtual 'Data File' type modules, where the choice and number of external connections are entirely at the whim of the user. (Having said that, however, some suggestions will be illustrated in Part 3.)

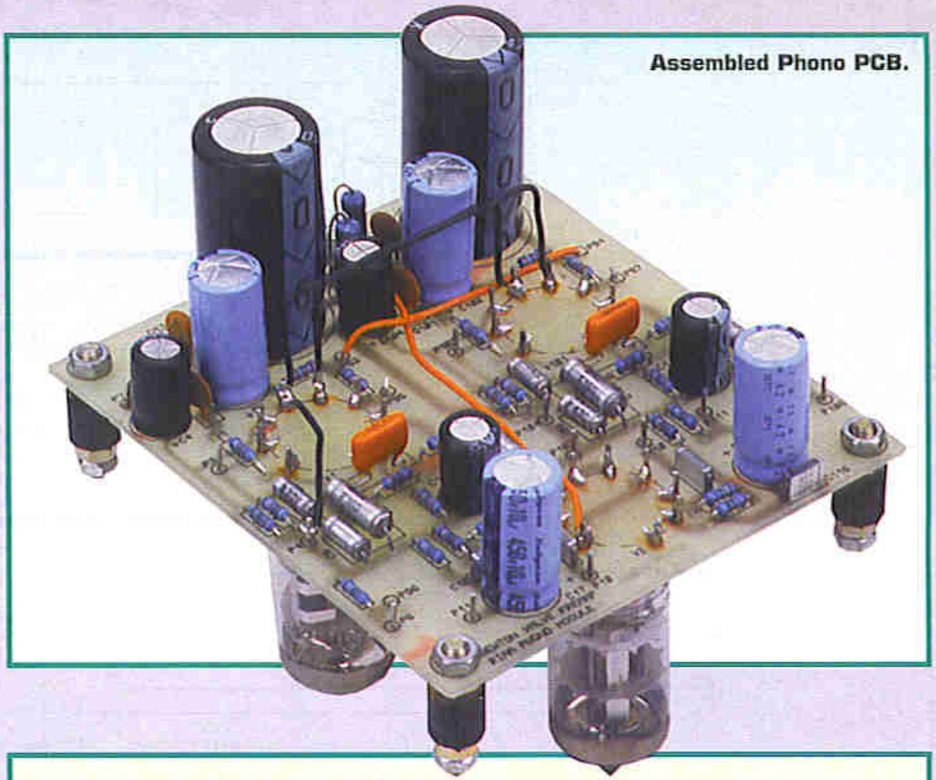
A word of warning before you start, though. In this case, the active electronic elements are valves, and as with all valves this involves the use of lethally high supply voltages. Consequently, as you design your ideal preamplifier as a complete system, that will do all you want it to, incorporate the following guidelines:

- YOU MUST only use the recommended power supply unit and build it absolutely according to the instructions.
- YOU MUST install the amplifier module PCBs in a fully enclosed and earthed chassis. The Phono Module Kit includes a 4 × 8 × 2·5 inch chassis, into which both this and the Tone Control PCB can be fitted if desired. Such a chassis must be physically joined to the PSU so that the supply cabling can pass directly between them.

The Complete Newton Preamplifier.

- YOU MUST take particular care with wiring up the HT power supply, chassis earth and common signal earth connections. Follow the accompanying wiring diagrams implicitly.
- YOU MUST NOT attempt to make your own PCBs – you can try 'hardwiring' in the good old fashioned way with tag boards and the like, IF YOU HAVE EXPERIENCE OF THIS, otherwise always use the ready-made PCB that includes a solder resist layer as an aid to insulation and user safety.

Outside these constraints, what type of signal connectors you use and precisely what you connect to the signal inputs and outputs and how you wire them up is up to you – although it would be prudent to use good quality screened cable for all inputs.



Assembled Phono PCB.

Specification of the complete system

Phono stage

Input impedance:	51kΩ + 330pF*
Line output impedance:	1kΩ
Overall gain, phono to line:	48dB @ 1kHz
Line output level:	1 to 2V peak (2·5mV @ 1kHz for 5cm/s)
Signal to noise ratio:	40 to 60dB (depending on cartridge)
RIAA equalisation network type:	Passive optimised

* Select values to match the requirements of the cartridge used.

Tone control stage

Line input impedance:	1MΩ
Main output (to power amp) impedance:	<10kΩ
Overall gain:	6dB flat
Frequency response:	20Hz to 20kHz ±0·5dB, –2dB @ 100kHz
Output noise:	<200µV peak max.
Signal to noise ratio:	60dB for 100mV input level
Line input signal level:	0dB typical
Maximum permissible input level before onset of clipping:	6V Pk-to-Pk
Bass boost and cut:	+16dB and –12dB @ 20Hz max.
Treble boost and cut:	+18dB and –19dB @ 20kHz max.
Balance offset boost:	+3dB max.
Tone control network type:	Passive Baxandall
Power supply:	230 to 240V @ 50Hz or 115 to 120V @ 60Hz
Power consumption:	30W approx.

The three basic modules consist of a complete Power Supply Unit, the self-contained RIAA equalised Phono Preamplifier PCB, and similarly a Tone Control PCB, the latter is described in Part 3. Each is available as a separate kit, where the PSU and the Phono Module each includes a suitable aluminium chassis. Figure 1 is a block diagram of the complete system using the three modules. The interconnections and switching arrangements shown here only serve to show what is possible. You may not, for example, want the line functions, but prefer more inputs from the selector, or you could do without the Tone Control Module.

RIAA Phono Preamplifier Module

During the latter decade of the valve era, while many power amplifier circuit designs were circulating amongst the DIY fraternity, there were comparatively few front-end preamplifier circuits. It seems, however, that a popular choice for home constructors was the so-called Mullard 'two-valve' and 'three-valve' designs. When we eventually examined

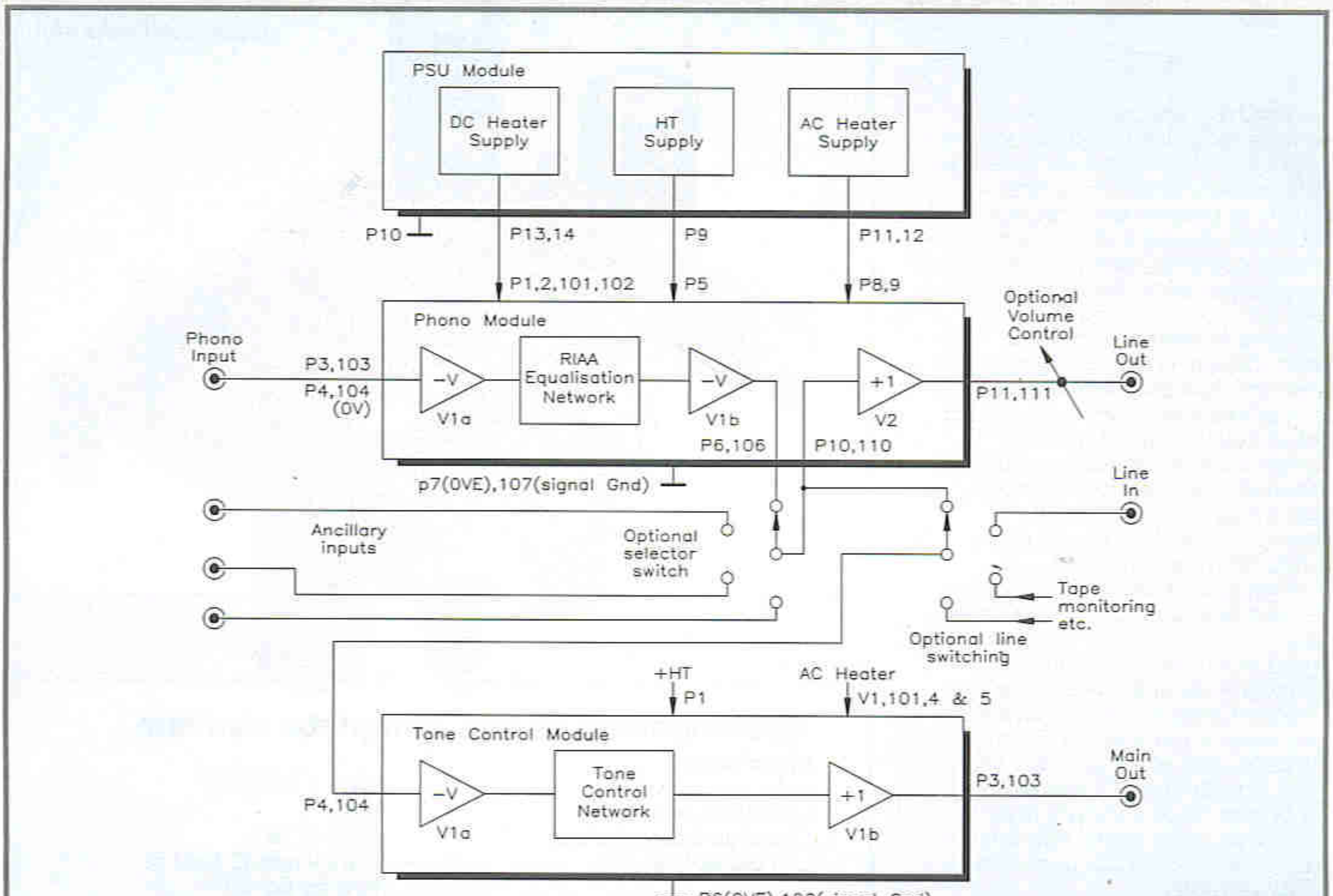


Figure 1. Overall block diagram.

the Mullard 'two-valve' in detail, it has to be said that we were singularly unimpressed with it. It was, I suspect, derived from a commercial design and as such is heavily compromised to cut production costs to a minimum. Consequently it has daft elements to it, such as the tape outlet that is merely tapped off an anode load, providing a low level signal intended for sending down a screened lead, but effectively in series with a 100kΩ resistor?

Really, though, the only phono equalised designs truly worth bothering with are dedicated ones, be they solid state or valve. So the search was on for an RIAA equalised preamp design and it turned up in the form of an RCA circuit. It also incorporated the passive RIAA equalisation network, which we wanted to compare with the now universal integral NFB type found in solid state designs. The Phono Module's specification is listed in Table 1.

Test conditions	
Input signal level:	2·5mV peak, 1kHz
Input source impedance:	600Ω via 1·5m screened lead
HT supply:	300V + 100mV ripple @ 100Hz
Input impedance:	51kΩ + 330pF*
Buffered output impedance (using V2):	<1kΩ
Overall gain:	48dB @ 1kHz
Output levels, with simulated magnetic cartridge input	
#1: moving coil, = 2·5mV @ 1kHz	630mV
Signal to noise ratio:	>39dB
#2: moving magnet, = 5·5mV @ 1kHz	1·5V
Signal to noise ratio:	>43dB
Real conditions (example = Tenorel TMC10 moving coil cartridge, O/P = 2·5mV @ 1kHz for 5cm/s)	
Output level in use:	2V peak
Signal to noise ratio:	>52dB (nearer 60dB)
V1a & b triode stage gain:	34dB each
Equalisation network type:	Passive RIAA standard
Power requirements:	
HT supply:	300 to 350V DC
HT current consumption:	15mA incl. buffer
Heater supply #1:	12·6V DC @ 300mA**
Heater supply #2:	6·3V AC @ 300mA

* Select values to match the requirements of the cartridge used.
** DC heater must be regulated and one side connected to signal I/P 0V near V1.

Table 1. RIAA Phono Module Specification.

Circuit Description

It can be seen in Figure 1 that the phono module also includes a unity gain line driver or buffer. This is necessary even if the phono module is intended to be used on its own, to provide sufficient output driving capability for interconnecting screened output leads with possibly a fairly low terminating impedance at the other end. Other elements can be interposed between the phono preamp proper and the line driver, such as a source selector switch, and if desired a volume or level control can be added across the driver's output.

Figure 2 shows one complete channel only of both the phono preamplifier and the line driver; all that is shown here is contained on the PCB. The other channel is identical, and they share only the few supply filtering components. The PCB is approximately 4sq.in. square yet carries all three valve envelopes and

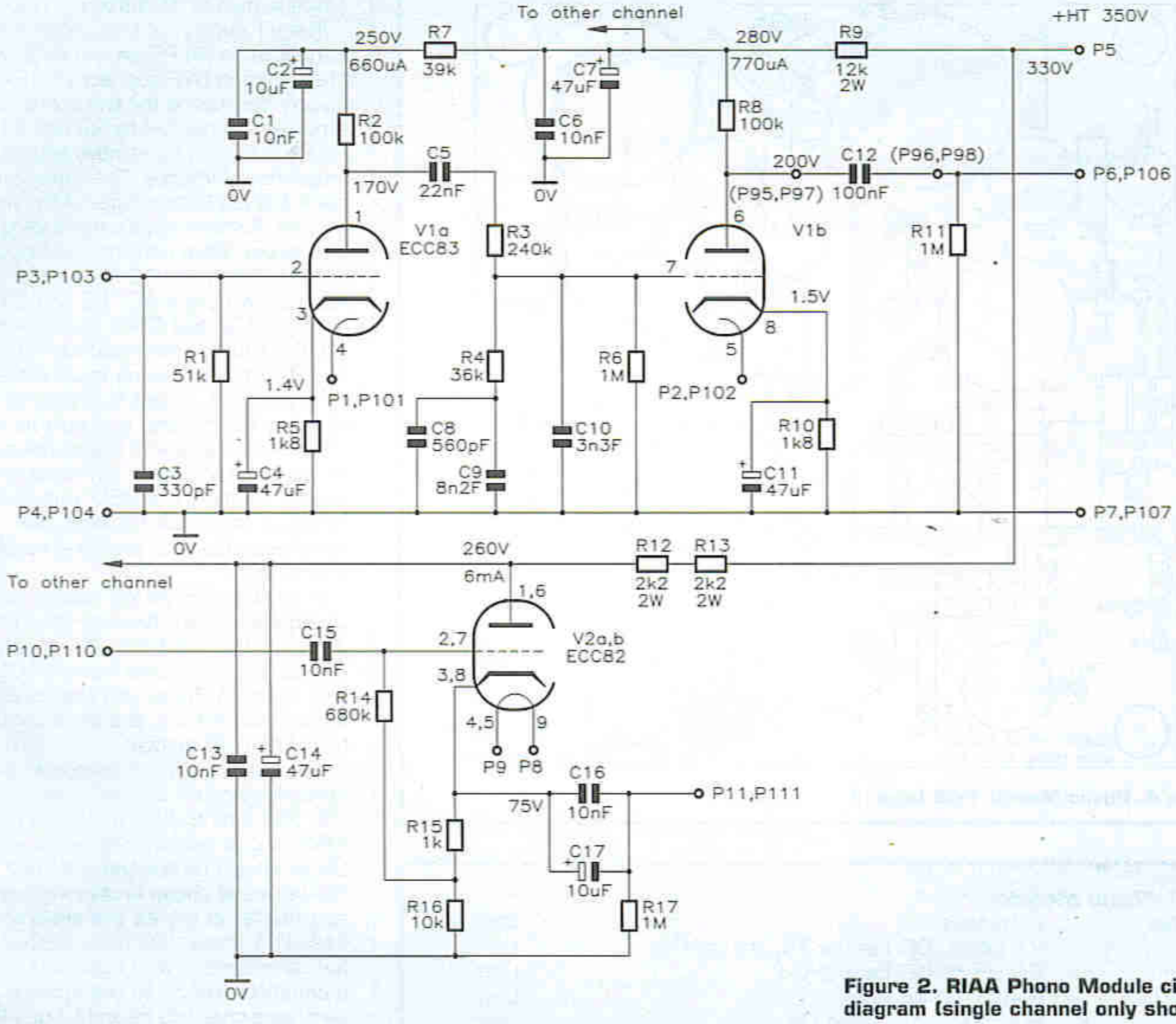


Figure 2. RIAA Phono Module circuit diagram (single channel only shown).

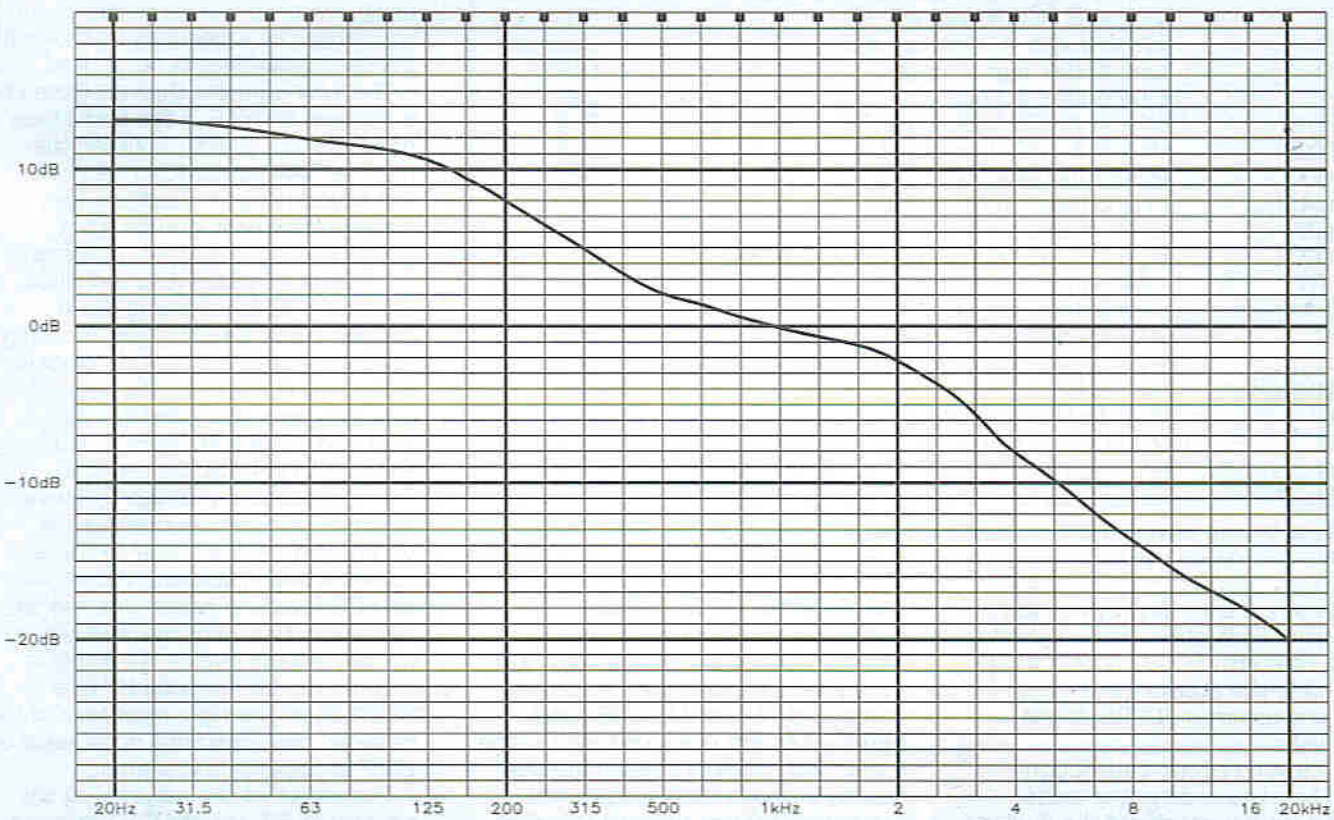


Figure 3. Phono Module RIAA response graph.

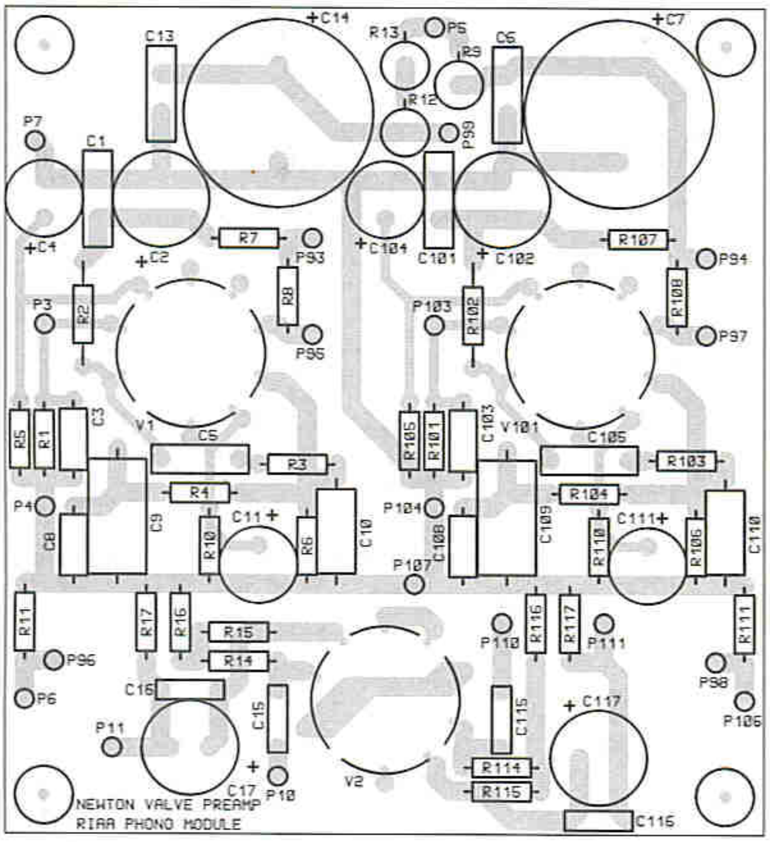


Figure 4. Phono Module PCB Legend.

RIAA Phono Module

Pin No.	Function	Channel
(P1)	V1 pin 4, DC heater (-), link to P4	Left
(P2)	V1 pin 5, DC heater (+)	Left
P3	Phono signal input	Left
P4	Phono input screen 0V	Left
P5	+HT supply	Common
P6	RIAA phono output	Left
P7	supply 0VE from earth bus (PSU)	Common
(P8)	V2 pin 9 AC heater #1	Common
(P9)	V2 pins 4,5 AC heater #2	Common
P10	Line buffer signal input	Left
P11	Line buffer output	Left
(P101)	V1 pin 4, DC heater (-)	Right
(P102)	V1 pin 5, DC heater (+)	Right
P103	Phono signal input	Right
P104	Phono input screen 0V	Right
P106	RIAA phono output	Right
P107	signal 0V for phono outputs & buffer	Common
P110	Line buffer signal input	Right
P111	Line buffer output	Right
P93	HT source for V1 stage via Link 1	Left
P94	V1 stage HT via Link 1	Left
P95	V1 pin 6 to C12	Left
P96	C12 to R11 and P6 (phono out)	Left
P97	V101 pin 6 to C112	Right
P98	C112 to R111 and P106 (phono out)	Right
P99	HT source for V2 stages via Link 2	Common

Table 2. Phono Module PCB pin designations

all the components directly associated with them. Each phono preamp circuit uses a complete ECC83 double triode valve, while the stereo line drivers share one common ECC82 double triode valve.

The following circuit description should help you understand better how the various stages of the module function, and aid any fault-finding or testing that you may need or want to carry out. The phono preamp comprises two identical triode amplifier stages in cascade. The RCA circuit naturally employed American valves. Here Mullard ECC83 small signal valves are used, and each stage is built with Mullard's recommended standard circuit configuration and component values. This ensures that the best possible performance is obtained from the valve and each stage has a signal gain of 34dB (voltage gain of 50 times).

The HT supply for the whole module connects to pin P5 on the PCB, while the common 0VE connects to P7. Supply decoupling for the stereo phono amplifier is provided by R9 and C7, with C6 helping to remove any high-frequency elements. This common point serves both stages V1b and V101b. Further supply decoupling is provided from here to the input stages, V1a and V101a, each of which has its own group R7, C2 and C1, and R107, C102 and C101, respectively.

HT is routed independently via R12 and R13 to decoupling capacitors C13 and C14, where it is shared by the two line drivers. It should be noted that this measure of supply decoupling is not only to remove any noise on the supply line from the PSU, but also to minimise crosstalk between the various stages and promote stable operation.

In addition a 6·3V AC heater supply is required for V2 (across valve pins 4+5 and 9), and 12·6V DC in parallel across V1 pins 4 and 5 and V101 pins 4 and 5. These are the six basic supply connections and come directly from the PSU module.

The signal from the magnetic pickup cartridge arrives at the phono input P3, 103 (and the earth return P4, 104), and is terminated by R1 and C3. It should be pointed out that the values of these two components as provided in the kit are arbitrary, based on those commonly quoted for cartridges of this type. To ensure a complete match to the specific cartridge that you intend to use you should install the values quoted in the cartridge's specifications. Due to the very high signal sensitivity in this area, using switches and extra components to change the impedance matching for different cartridges is not a good idea.

The 'raw' signal is then subjected to a flat gain of 34dB in the first stage of V1a, which directly sources the passive RIAA equalisation network. The actual network itself has been optimised for best results along similar lines to that first published in 1985 in *Wireless World* and since updated. (RCA's version is much simpler in comparison.) The frequency response contour of this network is illustrated in Figure 3. The network operates as a controlled low-pass filter comprising, in Figure 2, R3 in series with R4, C8, C9 and C10. These capacitors are high tolerance polystyrene types. The network is AC coupled to V1a anode by C5, a polyester type capacitor chosen for its 400V working range; one has to remember that until the valve warms up, the voltage level at its anode is actually the full unloaded HT level of 350V! Given the high impedance of the network, the apparently small value of 22nF is perfectly satisfactory.

The output of the network, at the junction of R3, R4 and C10, is taken directly to the signal grid of V1b. Resistor R6 provides the 'grid leak'

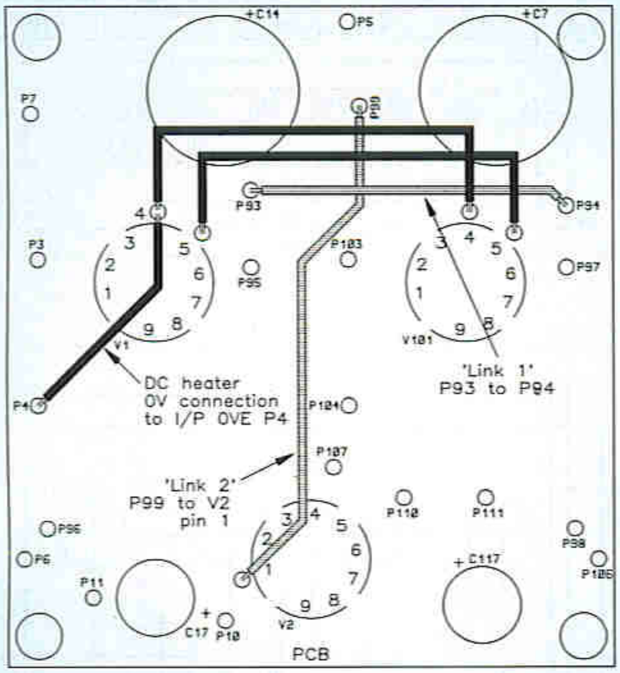


Figure 5. Phono Module onboard HT and heater wiring.

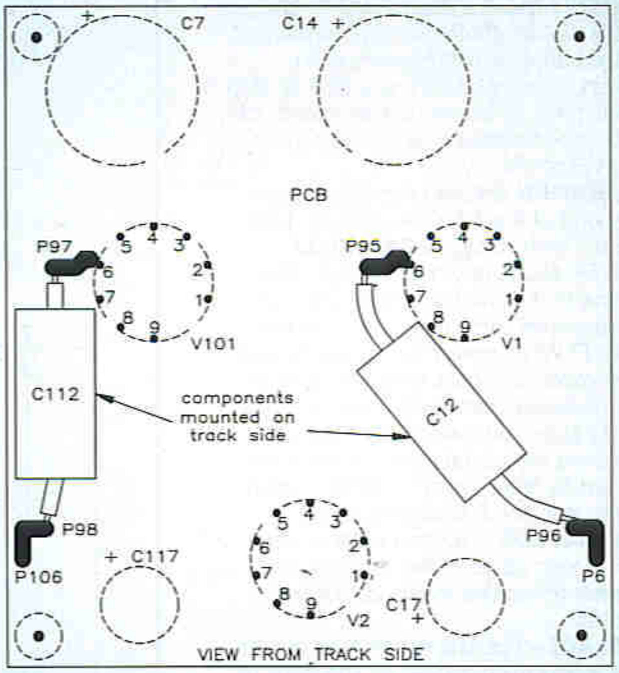


Figure 6. Mounting C12 & C112 to the track side of the Phono PCB.

or DC bias for the second triode and is at 0V potential. A value of 1MΩ ensures minimum loading of the network, yet provides a satisfactory grid bias for the valve.

At this point signal strength is quite reduced, a majority of the gain provided by V1a is lost in the network. A further 34dB of flat gain provided by V1b boosts this signal up to a much more satisfactory level for output. Overall, however, the amplifier is very efficient, producing approximately 2V – high enough to rival the output of the average CD player – from a signal supplied by a fairly low sensitivity moving coil cartridge. When one is accustomed to expecting 100 to 200mV from the solid state equivalents, this high level of output is quite extraordinary – try getting that from just two transistors!

The output is AC coupled from V1b anode with a 100nF polypropylene capacitor, having a very high insulation resistance and working voltage range, C12. Again this component has to handle maximum HT level until after warm-up. Its value allows the output to be loaded down to approximately 100kΩ with no loss in bass response. Resistor R11 ensures that the output side of C12 is referenced to 0V DC at all times. This is so that, if 'Phono' is chosen with a selector switch where previously it was not, the amplifier does not deliver a hefty pulse down the line to the rest of the system as C12 charges up!

The Line Driver

Each half of V2 forms the active element of the line driver or buffer. An ECC82 double triode is used here which has a higher current capability than the ECC83, and is better suited to this role. The identical stages follow the unity gain, non-inverting cathode follower configuration, with cathode bias properly derived from a series resistor chain, R15 and 16. The bulk of the voltage drop, which allows a sizeable signal voltage swing, is across R16 and is derived from a healthy anode current of 7mA. This leaves R15 to develop the actual cathode bias of 7V, with the lower end communicated to the signal grid via the grid leak resistor R14.

The input impedance of the stage is not determined by the value of R14 alone. The action of the cathode following the signal grid results in an impedance multiplying effect for R14, so that instead of being 680kΩ the actual input impedance is neare to 10MΩ. The small value of the polycarbonate capacitor, C15, which AC couples the input, is more than ample for this and the line driver would be extremely useful for buffering signal sources having a very high output impedance.

This line driver is very simple yet very capable, having a flat frequency response to at least 100kHz and is able to drive loads down to 1kΩ before signal quality is seriously degraded. This allows a fair degree of 'fan-out' for sourcing more than one item of external equipment whilst coping with the core to screen capacitance of cables; it is certainly able to drive 1·5m or more of consumer quality screened lead with no discernible losses.

AC coupling at the output is via C17, a high-voltage electrolytic. Generally electrolytics of this type are not a good choice for an audio signal path, but a high value is necessary to ensure good bass response into a (comparatively) low impedance load. However, HF performance is assured by C16. Alternatively you might replace these with an equivalent value made up from audio grade polypropylene types, but these are very large and will have to be connected off the board with the space to accommodate them.

R17 serves the same function as R11. One concern here was the

HT+ = 330V
Junction of R9, C7 = 280V
Junction of R7, C2 and R107, C102 = 250V

V1 Pin No.	Volts	V101 Pin No.	Volts	V2 Pin No.	Volts	
1	170	1	170	1	260	anode
2	0	2	0	2	68*	signal grid
3	1·4	3	1·4	3	75	cathode
6	200	6	200	6	260	anode^2
7	0	7	0	7	68*	signal grid^2
8	1·5	8	1·5	8	75	cathode^2

* = measure at junction of R15/16, R115/116. NOT at valve grid pin.

Table 3. RIAA Phono Module Voltage Test Points.

danger of inflicting any solid state circuits that are connected to the output of the buffer to high-voltage pulses on switching on or off. In practice though the transition is very slow, both at warm-up and switch-off, and peak deviations are rarely more than 2 or 3V.

WARNING! Before proceeding with any kind of work on this circuit, take heed – high voltages **CAN KILL!** NEVER touch any high-voltage part of the circuit with either fingers or uninsulated tools unless the power is OFF! While power is on, you should only touch any part of a circuit with an insulated test probe when required. Every time you switch off, adopt the following industrial safety procedure, known by the acronym 'SIDE', which spells out the following steps:

SWITCH OFF – Switch off the main PSU front panel rocker switch, and switch off at the mains outlet wall socket.

ISOLATE – Pull the mains lead out of the mains inlet socket at the back of the PSU.

DISCHARGE – Discharge the main line HT reservoir capacitor to zero volts (**NOT** with a screwdriver!).

EARTH – Earth the main line HT to chassis 0V with a leakage resistor to prevent any electrolytics recovering a charge from their own dielectric absorption.

In the design of the PSU 'earthing'and'discharging' is automatically taken care of by R2 in the PSU circuit. Please note that it may take the resistor up to one minute to completely discharge the unloaded HT to 0V. To make doubly sure, you **MUST** test the main line HT with a multimeter set to high DC volts before touching any part of any circuit. This shall hereon be referred to as 'the SIDE procedure'. **DON'T CUT CORNERS!**

Phono Module Construction

Refer to Figure 4 for the PCB legend. The PCB is a single-sided glass fibre type, and is strong enough to carry all the components including the valves in their holders. Note that it includes a solder resist layer on the track side, which will also help to minimise current 'creepage' across the surface between points of high potential difference when in use, for this reason the PCB track has not been shown.

Once the PCB has been assembled and tested, and is known to operate correctly and be ready for use, you are advised to apply conformal coating to the finished solder joints to augment this protection.

More detailed instructions are given in the leaflet (XV11M), but basically construction begins by inserting and soldering the 40 PCB pins at P3 to P7, P103 to P107, P10, P11, P110, P111, also at the three valve holder positions. In each case, insert and solder nine pins from the track side into the outer of the two concentric rings of holes for each valve holder; that with the smaller holes. Next, carefully insert the B9A valve holder into the board from the track side, into the inner ring (larger holes) until it is fully seated flat on the PCB. Each pin of the valve holder is then bound to its corresponding PCB pin with a turn of bared bell wire and soldered to it (c) don't be sparing with the solder).

Some 'spare' holes will be left over, P93 to P99. These do not have PCB pins. (Table 2 lists the functions of the various pins and links.)

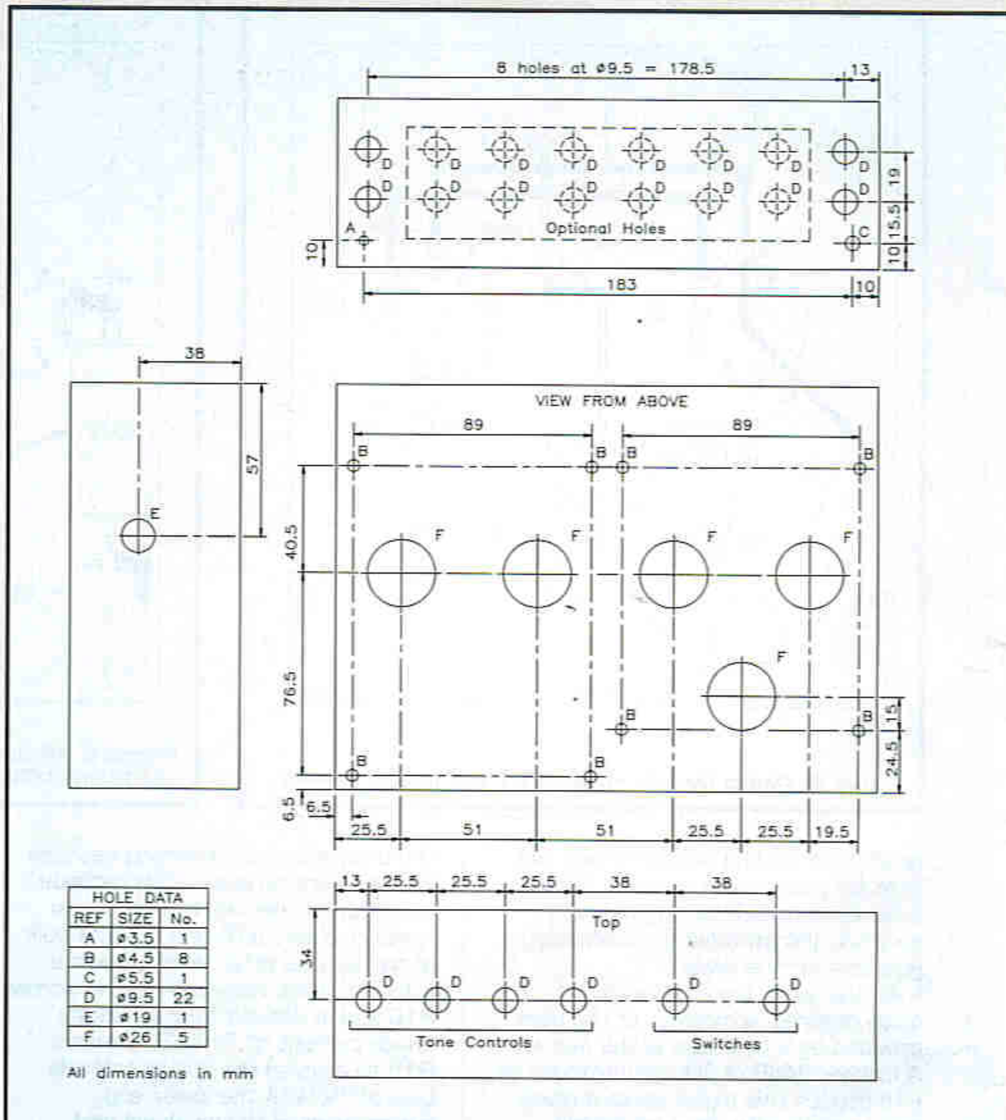
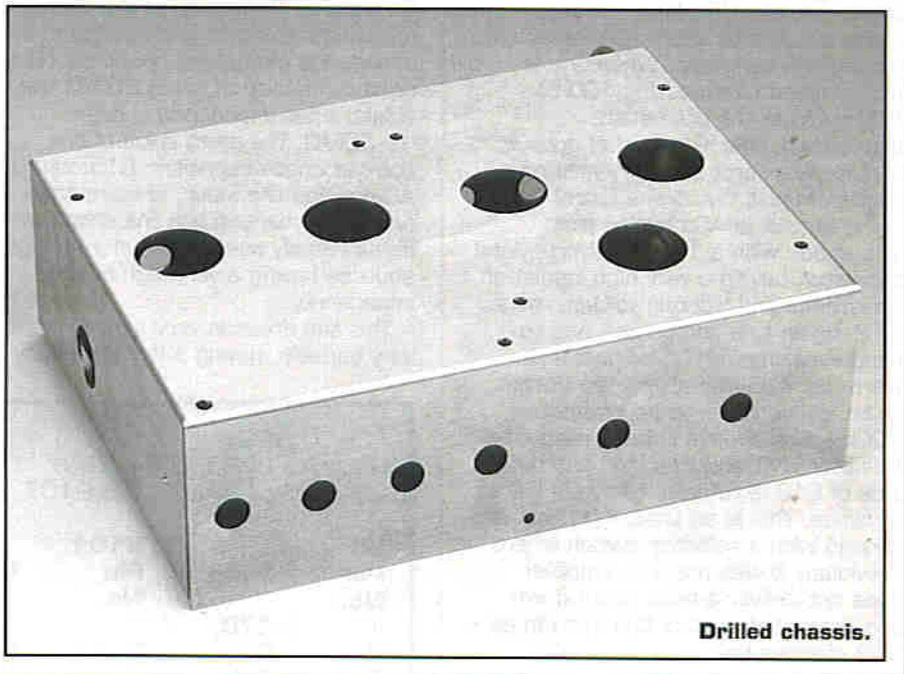
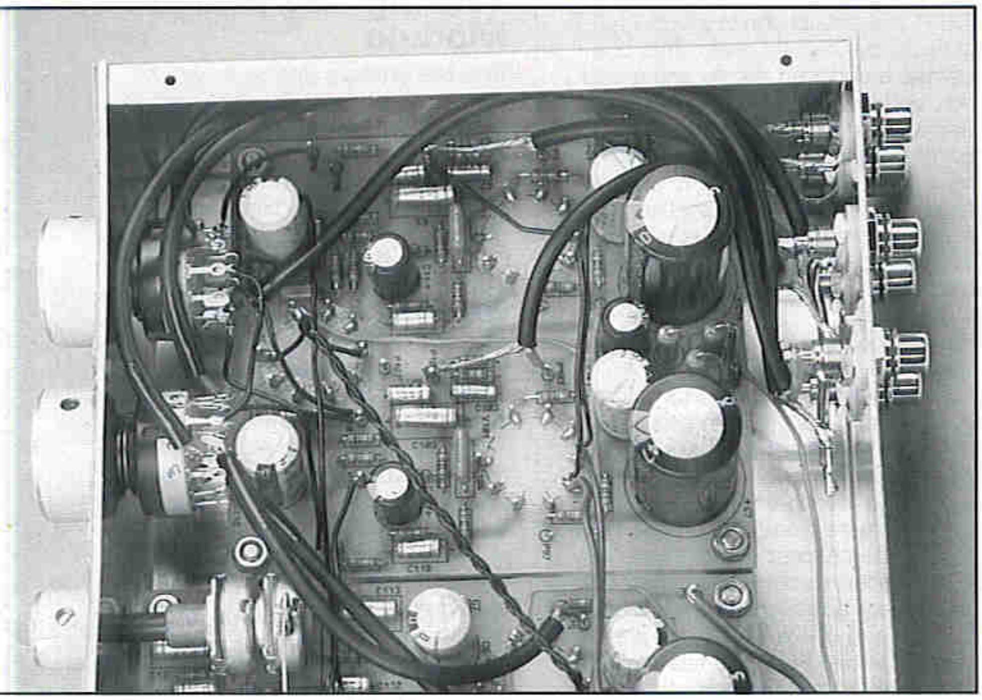


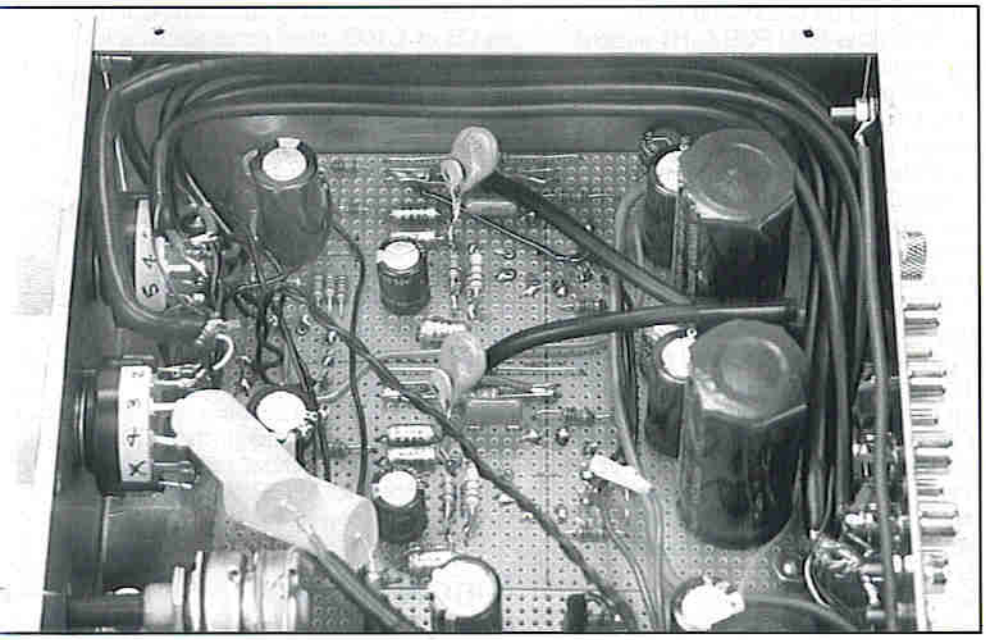
Figure 7. Phono Module chassis drilling details.



Drilled chassis.



The Phono PCB fitted into the chassis.



The prototype Phono module fitted into the chassis.

Components are installed by fitting the smallest first, working up to the largest. The 2W metal film resistors R9, R12 and R13 all stand on end to conserve space on the PCB and to aid cooling in use. For each, bend one lead to lay flat against the body of the resistor, and insert the component vertically orientating it to the PCB legend.

Using orange bell wire, link P99 (near R12) to V2 pin 1 near C15, as in Figure 5. Pin numbering for all the valves is clockwise as viewed from the component side of the board, and always with pin 9 at the bottom. The rings of PCB pins make all valve connections accessible, and the bell wire can be wrapped and soldered around that for V1 pin 1. This is 'Link 2' in Table 3.

Also link holes P93 and P94 with orange bell wire (Figure 15). With lengths of black bell wire, join V1 pin 4 to V101 pin 4, and V1 pin 5 to V101 pin 5, using the PCB pins, see Figure 7. It is not necessary to twist the wires together as in normal AC heater wiring practice (but there's no harm if you do).

Due to their physical size, it was more convenient, if a little unconventional, for the yellow polypropylene capacitors C12 and C112 to be mounted on the track side, as illustrated in Figure 6. The method of mounting the PCB allows plenty of room. Cover exposed lengths of lead with sleeving stripped from power connection wire or mains cable. C12 connects between P95 and P96, while C112 is between P97 and P98, ON THE TRACK SIDE. The leads are pushed through the holes and bent over and cropped as usual, but soldered on the track side where they enter each hole.

Finally prepare the four rubber couplings these will be used as mounting pillars for the PCB. Remove the spring washers from each and replace the nuts and tighten carefully, to avoid splitting the rubber. The final distance will be approximately 17mm. Using the extra M4 nuts provided in the kit, attach each coupling to the PCB mounting holes on the track side. In use the PCB hangs upside down in the chassis, while the three valves will protrude through holes in the chassis top panel. Temporarily set aside the assembled PCB while you prepare the chassis.

Preparing the Amplifier Chassis

Drilling and cutting details for the chassis for the amplifier section is shown in Figure 7. The removable lid is the bottom of the box. The $^3/_8$in. holes in the rear panel are for gold plated phono sockets (JZ05F (black) and JZ06G (red)), which come with insulating shoulder washers, since the 0V side of the sockets must be isolated from the chassis. Alternatively, you might use an 8-way phono socket on a paxolin panel (with 4 × M3 fixing holes), for which a rectangular cut-out is required. It can also include an earthing terminal post for a record deck, see optional parts list.

The left-hand side panel has a $^3/_4$in. diameter hole whose position corresponds with the grommet on the PSU chassis, allowing the two chassis to be joined end to end.

The top panel has 1in. diameter holes, preferably made with a round sheet-metal punch, to clear the valve envelopes when the PCBs are in place. The Phono PCB must be on the right-hand side (three valve holes) furthest away from the PSU. If the Tone Control Module is not used then the two left-hand valve clearance holes and associated M4 clearance mounting holes are not required.

Combining the Chassis

When the PSU and amplifier chassis are joined end to end, the complete assembly becomes 16in. wide which is a typical width for most stereo items. The rear join should be made with a rectangle of aluminium plate $2^1/_2$in. high × 1in. wide with a hole at each corner for fixing, using M4 hardware or pop rivets. Ideally the front should have a covering front panel cut from 16 swg aluminium sheet (see optional parts list). All frontal holes will be duplicated in this panel. It can be any height you like (the prototype is $4^1/_2$in. high to fill a gap between two shelves). The separate front panel is rigidly attached to both chassis by M3 hardware in each corner of the front panels of both chassis. The panel can be painted, and countersunk screws allow a stick-on design to be attached, completely hiding the fixings (and the fixing screw for RG1, see the PSU Module). Figure 8 shows the front and rear panel legends available as an optional item.

Installing the Phono Module PCB

The four flexible rubber couplings that are used as mounting pillars for the PCB should, as already described, be fitted onto the PCB first. Experience has indicated that it is much easier to insert the threaded ends of the pillars through the chassis when the PCB is fitted, rather than the PCB over the pillars. (This is especially true of the Tone Control PCB, which is larger.) Because the mountings are flexible, it is a simple matter to 'hook' the studs through the chassis panel with a thin-bladed screwdriver. Secure all four studs with the four M4 nuts and DO NOT over-tighten, or there is a risk of damage to the rubber. You will find that any rotary switches will have to be fitted after the PCB is in place, as space is rather tight.

If you are also going to mount the Tone Control PCB later, be aware that rotary switches AND the Phono PCB will have to be removed again to make room for manoeuvring the Tone Control PCB into position (mainly because of the four control spindles). It is not too difficult to disconnect and reattach the PCB pin connections, and all wiring can remain connected to the rotary switches while they are removed.

Power Supply Wiring to the Phono Module

Figure 9a shows the basic essential wiring between the Phono PCB and PSU. While signal connections are flexible, these connections are not and these instructions must be adhered to.

Firstly establish what is called an 'earth bus', which shall connect ALL the signal earth tags of however many phono sockets are fitted together, EXCEPT the actual phono input pair (from the record deck). This bus becomes a common supply and signal earth, and should be isolated from chassis and mains earth, which is a separate system. Use stripped bell wire or tinned copper wire. It will be noticed that there is an approximate 1in. gap between the rear edge of the PCB and the rear panel for wiring and socket connections along the back of the chassis.

Next fasten the earth strap (green/yellow wire) from the PSU to the amplifier chassis with its M3 solder tag, using an M3 × 10mm bolt, nut and TWO shakeproof washers (see Figure 10a).

Connect a length of green power connection wire from P10 on the PSU PCB and the nearest end of the earth bus (all routes through the grommet). Also connect green power wire from the other end of the earth bus and P7 on the Phono PCB. The heavy gauge of this cable is quite important, it provides the minimum resistance for all signal and supply earth returns, ensuring good performance. Don't be sparing with the solder.

Connect P5 on the Phono PCB with P9 on the PSU PCB (+HT supply) using orange bell wire. Connect the PCB pins of V101 pins 4 & 5 to P14 & P13 on the PSU PCB using stranded brown hook-up wire. V101 pin 4 (referenced to 0V by a link on the board) must connect to P14 (DC heater supply -V).

Finally, connect V2 pin 4 or 5 (they are linked by a track) and V2 pin 9 to P11 & P12 on the PSU PCB using a tightly twisted pair of black bell wires. The pair should rise vertically to a level of 1in. above the PCB surface before going directly to the grommet, avoiding the areas of V1, V101 and associated components.

These are the six vital connections to the Phono PCB and they do not deviate. See also Table 2 for overall PCB pin designations.

Turn the chassis over and plug in the valves – V1 & V101 = ECC83, V2 = ECC82. The Phono Module should now be operational and ready for initial testing.

Testing the Phono Module

Turn the chassis upside down and support it to keep the three valves clear of the work surface. Connect the Euro mains lead and switch on. In a short time you should be able to establish that all three valves are glowing. If not, perform the complete SIDE procedure and examine the heater supply wiring for errors.

WARNING! Never heat valve holder pins with a soldering iron while a valve is still plugged in; remove it first. (Heating a valve pin too quickly risks cracking the glass envelope.)

If all valves are glowing, then the basic DC voltages around the circuit can be checked with reference to Table 3 (test points). Due to the vagaries of the HT supply, these levels are approximate, but measured values should not deviate greatly, a drastic difference will show an obvious fault. As opposed to semiconductors, it is most unlikely that a valve is damaged by a serious fault, at least in the short term, since they are, electrically speaking, extremely tough. If, however, you have a short circuit somehow across a DC blocking capacitor, such as C5 or C105, then other capacitors may be damaged, such as the polystyrene types which are not high voltage rated.

If the DC tests are good you may go on to AC testing if you have the equipment, such as an AF signal generator and oscilloscope. This will show whether the two identical circuits perform the same, if not, one of them has a fault. Dry joints in the equalisation network can produce some weird effects.

If a fault is found carry out the complete S.I.D.E. procedure before rectifying it. At this stage the PCB may be removed without completely disconnecting it, AFTER the valves have been removed!

Signal Wiring

Figure 9b attempts to illustrate some signal wiring options for the Phono Module, particularly if used alone. The extra phono sockets and selector

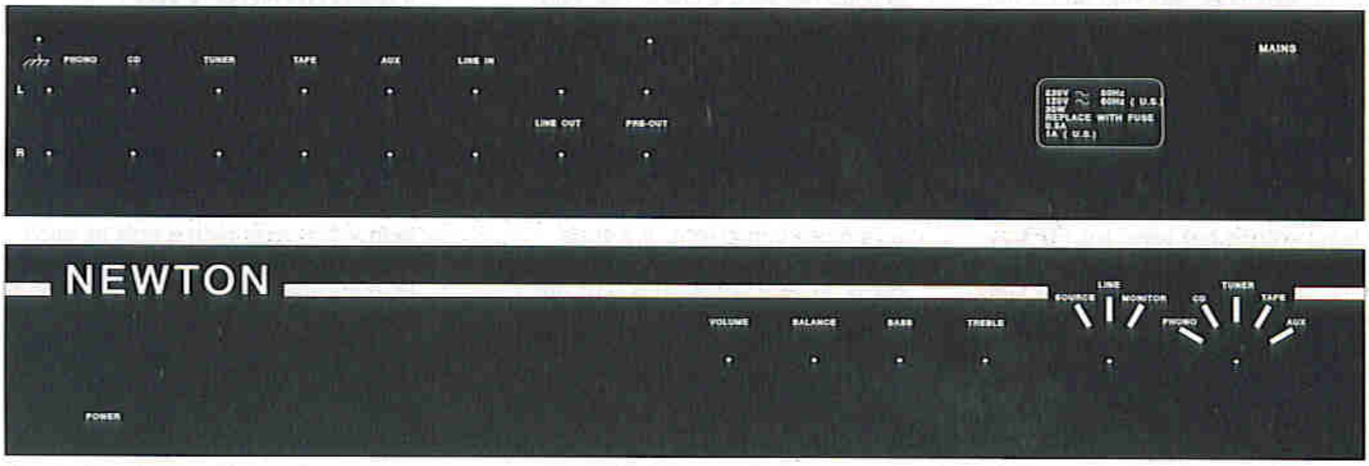


Figure 8. Newton Preamplifier Phone Module front/rear panel label. Scale: $^{7}/_{16}$in. = 1in.

Figure 9a. Basic general earth and supply wiring for the Phono Module.

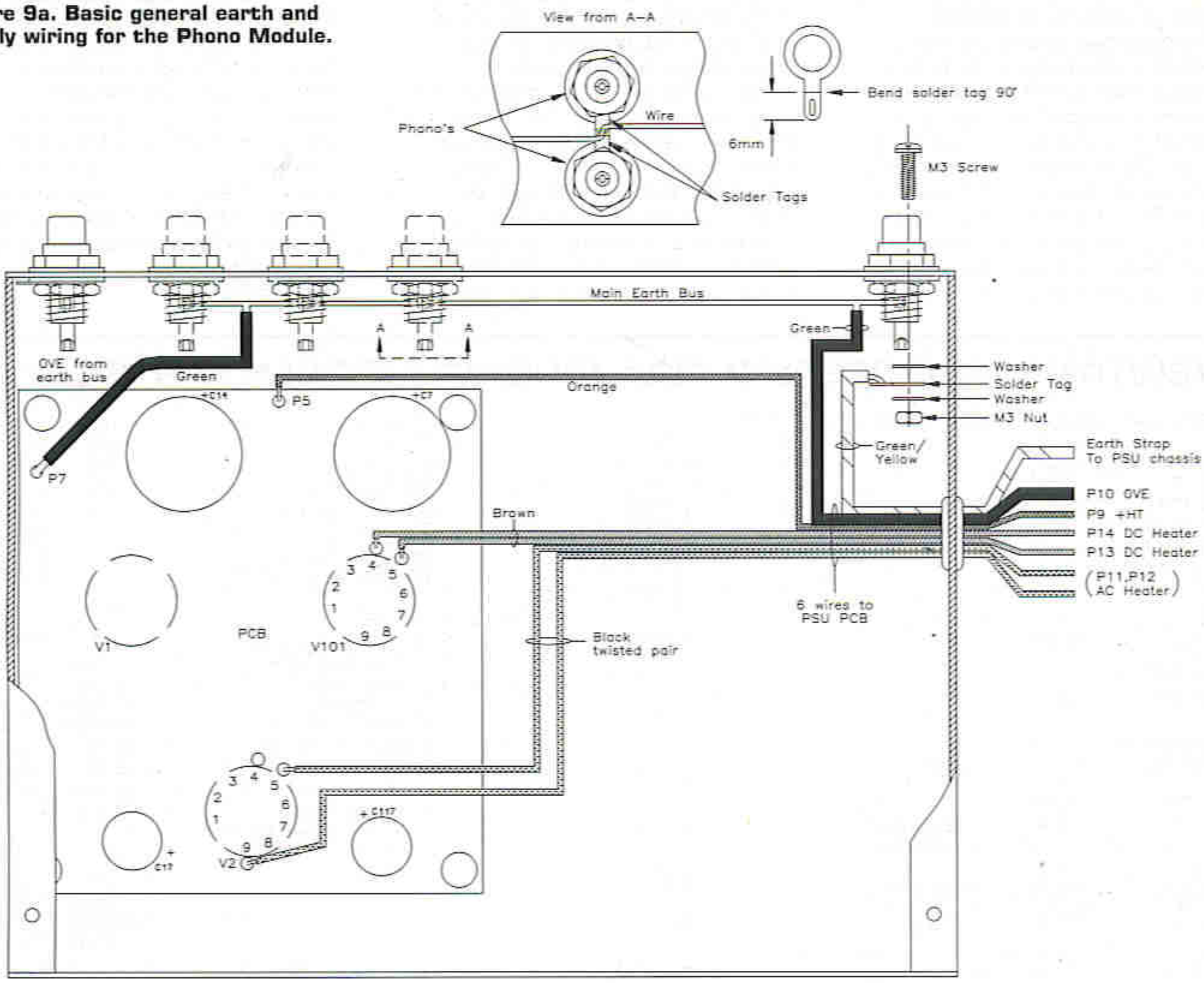
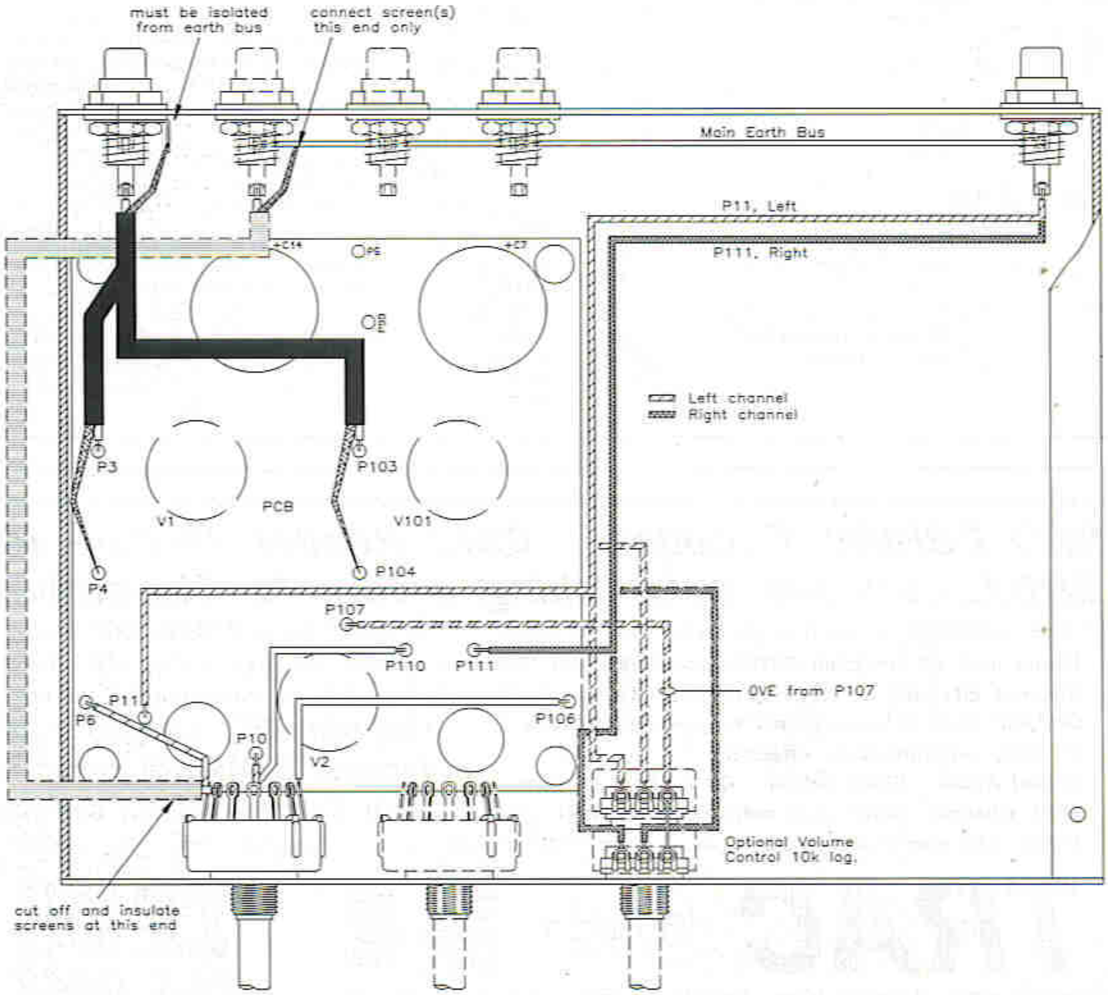


Figure 9b. Signal wiring diagram.



switch are purely optional, as is the dual ganged volume control (alternatively two singles can be considered). Volume controls should preferably follow the line driver, as this keeps the signal to noise ratio proportional to the output level at all settings. Signal source and switching options will be discussed in more depth in Part 3 (see also Figure 1).

The signal earths of the stereo pair of 'real' phono input sockets should *not* be included in the earth bus arrangement; due to the sensitivity of the amplifiers and the low signal level this is not possible without unacceptable noise and pickup. Consequently the metal body of each is connected to signal 0V on the PCB (P4, 104) via the screen of its own connecting cable ONLY. Furthermore the socket earths should not be linked together, or to the earth bus as well, or a 'hum-loop' will be formed. Ultimately each socket completes a circuit with its own side of the magnetic cartridge in the record player, the two signal returns remaining isolated along their length. Note that the centre conductors of the internal screened cables should be as short as possible at the phono socket tags and at P3 & P103. The distance to the signal 0V pins P4 & P104 is made with the screen braid only.

Part 3 will describe the Tone Control Module and more detailed signal wiring options for a complete valve preamplifier.

NEWTON VALVE PREAMP RIAA (PHONO) MODULE PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1,101	51k	2	(M51K)
R2,8,102,108	100k	4	(M100K)
R3,103	240k	2	(M240K)
R4,104	36k	2	(M36K)
R5,10,105,110	1k8	4	(M1K8)
R6,11,17,106,111,117	1M	6	(M1M)
R7,107	39k	2	(M39K)
R9	12k 2W	1	(D12K)
R12,13	2k2 2W	2	(D2K2)
R14,114	680k	2	(M680K)
R15,115	1k	2	(M1K)
R16,116	10k	2	(M10K)
CAPACITORS			
C1,6,13,101	High-Voltage Disc Ceramic 10nF 500V	4	(BX15R)
C2,102	Radial Electrolytic 10µF 450V	2	(JL11M)
C3,103	1% Polystyrene 330pF 500V	2	(BX51F)
C4,11,104,111	Low ESR Radial Electrolytic 47µF 50V	4	(JL47B)
C5,105	Polyester Film 22nF 400V	2	(BX72P)
C7,14	Radial Electrolytic 47µF 450V	2	(JL18U)
C8,108	1% Polystyrene 560pF 125V	2	(BX54J)
C9,109	1% Polystyrene 8n2F 63V	2	(BX85G)
C10,110	1% Polystyrene 3n3F 63V	2	(BX62S)
C12,112	Polypropylene 100nF 1000V (Class X/Y)	2	(FA21X)
C15,16,115,116	Polyester Layer 10nF 400V	4	(WW29G)
VALVES			
V1,101	ECC83	2	(CR27E)
V2	ECC82	1	(CR26D)
MISCELLANEOUS			
	Single Ended 1mm PCB Pin	1 Pkt	(FL24B)
	PCB B9A Valve Base	3	(CR32K)
	Aluminium Chassis AC86	1	(XB68Y)
	Single Screened Cable	1	(XR16S)
	1·5A Solid Core Wire Orange (10m)	1 Pk	(BL90X)
	1·5A Solid Core Wire Black (10m)	1 Pk	(BL85G)
	1·4A Wire Brown (10m)	1 Pk	(BL02C)
	6A Green Wire	1m	(XR35Q)
	Rubber Coupling	4	(FB98G)
	M3 × 10mm Steel Bolt	1 Pkt	(JY22Y)
	M3 Steel Nut	1 Pkt	(JD61R)
	M3 Shakeproof Washer	1 Pkt	(BF44X)
	M4 Steel Nut	1 Pkt	(JD60Q)
	Front Panel Label	1	(KP75S)
	PCB	1	(GH99H)
	Instruction Leaflet	1	(XV11M)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	Square Stick-on Feet	1 Pkt	(FD75S)
	2-pole 6-way Rotary Switch	As Req.	(FF74R)
	4-pole 3-way Rotary Switch	As Req.	(FF76H)
	Twin Phono Socket	As Req.	(JK15R)
	Quad Phono Socket	As Req.	(BW74R)
	Octal Phono Socket	As Req.	(JK17T)
	Gold Phono Socket Black	As Req.	(JZ05F)
	Gold Phono Socket Red	As Req.	(JZ06G)
	Grounding Post	As Req.	(JL99H)
	Aluminium Sheet 16 swg	1 Sht	(LH13P)
	Knob K8C	As Req.	(YR66W)
	M3 Shakeproof Washer	1 Pkt	(BF44X)
	M3 Steel Nut	1 Pkt	(JD61R)
	M3 × 10mm Steel Bolt	1 Pkt	(JY22Y)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available as kits, which offers a saving over buying the parts separately.

Order As LT76H (Newton Phono Kit) Price £34.99A1

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately, but are not shown in the 1995 Maplin Catalogue.

Newton Phono PCB **Order As GH99H Price £3.99**

Newton Preamp Label **Order As KP75S Price £2.99**

AIR YOUR VIEWS

S·T·A·R L·E·T·T·E·R

In this issue Mr M. R. Perry, of Kidderminster, Worcestershire, wins the Star Letter Award of a Maplin £5 Gift Token for his letter concerning heating economy.

★★★★★★★★★★★★★★★★★★★★

Heating Economy Devices

Dear Sir,
Concerning the idea of using various devices for reducing heating bills, you may be aware that there are a number on the market that claim to do just that, by a variety of ways.
However, reports by independent consumer groups tend to indicate that the savings quoted by the manufacturer are 'somewhat over optimistic', as with the claims often made for petrol saving devices on cars. In fact the cost of such devices, in my opinion, have to be spread over many years before, or even if, any actual saving is made.
I recently experimented with some fluorescent lamps in place of conventional light bulbs. It worked out that 5 years was needed to equal the cost of buying new bulbs in that time, at the end of which the fluorescent tubes will need to be replaced anyway!
The obvious way to reduce heating bills is not to use so much fuel, by simply turning down the heat. Is it really economical to pay over £100 for a device which does this for you? I have built my own boiler control device, yet it is still difficult to determine whether it actually saves fuel. It could be argued that it takes more fuel to keep reheating an almost cold boiler than maintain one varying by say 10°F.

The fuel saving devices that I have come across work by preventing the boiler from cycling on and off over short periods of time, instead the boiler is allowed to fire up for a given minimum period of time and then after it turns off, it is prevented from firing up again within a given period.
To calculate the most cost-effective method of heating a property involves a number of parameters, not least heat input into the system, heat output from radiators, losses within the system (up the flue, pipes, through walls and windows), the 'inertia' in the system (how long a room takes to heat up or cool down), internal and external temperatures, and how long the heating is to be on for in a 24hr period. Obviously there is an optimum arrangement, but it will be different in every property. If there is such a thing, there may be a thermal model for an 'average' property, a fuel saving device could be optimised for such, but how worthwhile such a device is, taking into account the variations about the average, could only be conclusively proved by extensive independent research on a wide range of properties. It is even possible that such devices in the 'wrong' property could actually increase heating costs not decrease them! The only guaranteed way to decrease fuel usage, other than improving insulation and having an efficient system that is regularly serviced, is to put on a jumper and turn the heating down (or off!).

★★★★★★★★★★★★★★★★★★★★

Classifieds Really Work

Dear Sir,
May I say a big thank-you for placing my request for a four-track reel to reel recorder in the classified advertisements section of your famous magazine. I am pleased to say that I have received three contacts, and of these one resulted in a most satisfactory settlement.
Richard Anderson, Cleveland.

We're glad that the service was of help to you. Don't forget that the classified's reach some 30,000 readers every month.

DIY Radio Alarm

Dear Editor,
The 418MHz encoded Tx and Rx modules featured in Issue 83, and the additional information in Issue 73 'Data File' are an excellent basis for a radio linked alarm system connecting one detection zone to a central control. I envisage several protected zones where each zone detector has its own Tx, and provided they are all encoded the same, then only one Rx would be sufficient to indicate an alarm state.
However, the system gets more complicated where it might be necessary for each zone to identify itself to the control, requiring each Tx to be coded differently and the receiver having duplicated decoders. Also a typical alarm system's sensor may have a normally closed relay loop preventing intruders cutting wires; this may be difficult to emulate for powering the Tx.
N. L. Smith, Stoke-on-Trent.

By using different encoder chips with the 418MHz transmitter and receiver modules (the PCB is designed to accept the specified device only) it is possible to transmit four bits of data (from several transmitters) to a receiver with a single address. The chips to use are the M145026, M145027 or the HT12E, HT12D (see pages 742 and 743 of the 1994-5 Maplin Catalogue) these chips are used in pairs, the first is the encoder and the second is the decoder. Data sheets are available on these devices. Further applications information for the 418MHz modules can be found in Issue 73, January 1994 of Electronics. *Data sheets are also available for the 418MHz modules, they are very comprehensive and include applications circuits based on the HT12 devices. A very comprehensive 418MHz development kit is available as a special order (DM52G) which includes Tx/Rx modules, PCBs, development components and full data, good value but costs £129.99 B1! Data sheets are 80p NV each, order as DS00A, don't forget to specify the device and stock code of the device you want data on! Data sheets can be ordered by mail order (using the order form or Tel: (01702) 554161). Maplin's Regional Stores do not stock data sheets, but you can order and pay for them at any of the stores. We already stock and sell two complete 'Wireless Alarm' systems, stock code XS57M (£99.99 E6) and AQ39N (£199.99 E8), using the principle you describe, you can find them, together with other accessories, on pages 12 and 13 of the 1994/5 Maplin Catalogue). Making your own security system using several 418MHz Tx/Rx modules is perfectly possible – but buying ready built will be cheaper and quicker, but not as much fun!*

Pictures Getting Smaller

Dear Editor,
Since it is becoming increasingly obvious that the TV moguls are determined to force us to watch pictures (and not just films) with *black* borders top and bottom, if not all around the edges, how about coming up with a 'picture expander' gadget?
I realise it would have to be self-contained, but could be installed between the video and the TV set, where the video is used as the receiver. I've tried to design one but can not get the ICs. I've been told – by a German – that such gadgets are available on the continent, but he couldn't supply the details. Is this possible?
Ronald Young, Sussex.

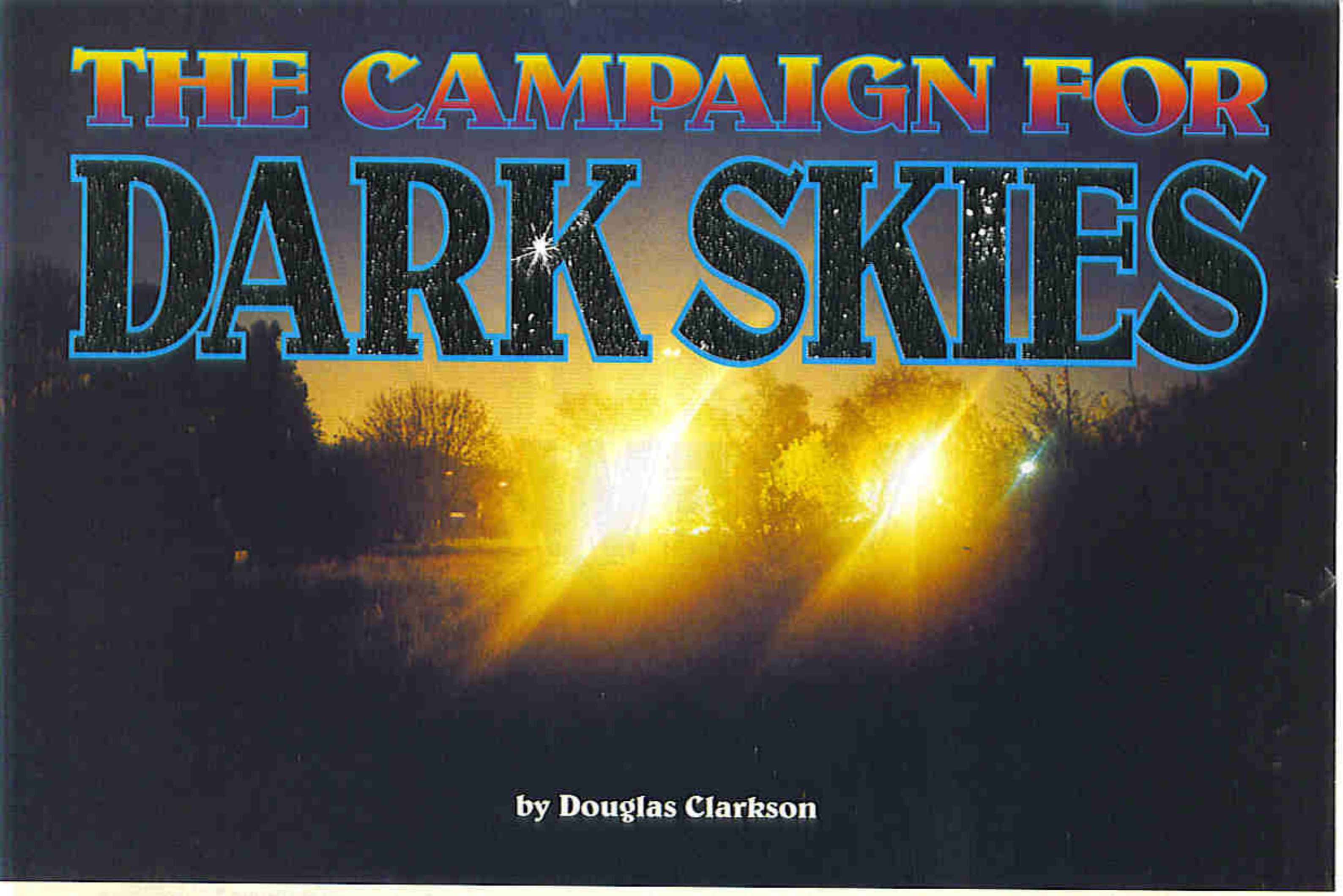
The reason why many films have black borders top and bottom is that most feature films, originally intended for cinema release, are filmed in a wide screen format, such as Panavision, etc. This allows much more action to be packed in and fills more of your field of vision (adding to excitement and realism) when screened at a cinema. The height to width ratio of the picture is known as the aspect ratio. The aspect ratio of standard TV tubes is different (sometimes very different) to the aspect ratio of film, so when films are broadcast, the TV company has two choices: concentrate on the middle part of the frame so that the picture fills the whole screen (it is cropped, so you loose chunks off the left- and right-hand edges); or broadcast the whole frame, letter-box format, with black borders top and bottom. The choice made will depend on whether the film is intended for mainstream or minority viewing, whether the film is suitable for cropping (some definitely aren't) and what is felt to be most popular at the time (TV companies do a lot of research into this). With cropped films, sometimes the main action spills into the cropped section, so the telecine equipment (the device used to convert physical pictures on film into an electronic TV video signal) has to pan across the scene to follow the action. Film buffs on the whole don't like cropped films – they say it's a bit like viewing the world with blinkers on! Incidentally, at cinemas, the curtains above, below and to the sides of the screen are movable to accommodate the different film aspect ratios used, exposing only the right amount of screen.
Wide-screen TVs are available, with aspect ratios closer to that of film, they also have built-in digital frame stores that allow the viewer to have some control over how the picture is displayed (zoom in and out). Such circuitry is available in external boxes, but certainly not practical as a project.
A new system called PALplus is being used to transmit wide-screen programmes to compatible wide-screen TVs, it works by transmitting the extra picture information to the left and right of the main picture in unused video lines in the vertical blanking interval, the receiver decodes this information and adds it onto the sides of the picture, clever, Eh!. The advantage being that on non-PALplus TVs a conventional full picture is displayed.
Generally the direction is towards transmitting films full frame, so you are likely to see more and more films, and TV programmes, broadcast in letter-box format. It is possible to increase the TV picture height to get rid of the black borders, but to maintain correct proportions you would have to increase the picture width as well, otherwise people will look very tall and thin. TVs have controls inside for adjusting picture geometry, so within certain limits the picture could be expanded, but if you don't know how, you shouldn't be poking around inside anyway. Colour TVs have an EHT voltage of some 25 to 30kV, and there are plenty of places around the power supply, line output and video output stages that will deliver very nasty, potentially lethal shocks. I know, I used to be a TV engineer.

Don't Call Back

Dear Sir,
No, you do NOT 'need to ring a friend and ask to be 'phoned back . . .' when testing the Telephone Bell Repeater (Electronics Issue 83 (November)). As hobbyists are now allowed to extend their own telephone systems, I thought that the following information would be of general benefit.
BT exchanges incorporate a ring-back self-test for which there is no charge. Lift the receiver off-hook, wait for the dialling tone; dial 174; wait for the continuous 'number unobtainable' (NU) tone, then replace receiver on hook. The exchange will then automatically ring you back instantly. To cancel the ring – just answer it!
Godfrey Manning, Middlesex.

This is a very useful tip for anyone wishing to check out their telephone line, however it doesn't work in all areas, if you call BT engineers (151) they will tell you the ring-back test number for your exchange. We already knew about the existence of the ring-back test number, but because of the need to dial a different code in different areas, we thought it would confuse matters!

THE CAMPAIGN FOR DARK SKIES



by Douglas Clarkson

Above: Photo 1. Car park, Eynsford in Kent. Rural light intrusion. Astronomer Richard Murrin, who lives nearby, has had his observing seriously curtailed by 'overkill' in the name of security. ©Copyright Richard Murrin.

NOWADAYS, it is quite reasonable for a child to ask, "Daddy, why is the sky all orange at night so that I can hardly see the stars?"

"Well, its the streetlights – we need them so that we can see and be seen at night when we walk about and when mummy or I drive the car. There's really nothing we can do about it."

This is in fact the wrong answer. The environmentally correct answer would now go something like this:

"I'm afraid this has come about because people have used the wrong type of lights which send light up into the sky instead of down to the ground, which is where everybody knows it really needs to go. People are now beginning to try to put things right (but there are a lot of streetlights that will need to be changed), but it could take some time."

It is only recently that national and international campaigns have become mobilised into combating light pollution and advocating a 'Dark Skies' policy. In the UK, the Campaign for Dark Skies – a group affiliated to the British Astronomical Association has already succeeded in raising awareness of the problem with a broad range of official groups. At an international level, the International Dark Skies Association co-ordinates activities on a wider scale. A notable success of the UK group was the inclusion of the entry – 'Light above the horizontal should be minimised as it is wasteful and increases sky glow' in BS5489 Part 1 (1992).

The extent of present levels of light pollution is dramatically indicated by pictures taken from satellites which show that there are very few areas in the UK with 'Dark Skies'. This implies that perhaps the majority of inhabitants of the UK are now denied a clear view of the night sky. The wonders of the Milky Way are now only to be experienced in text books on astronomy.

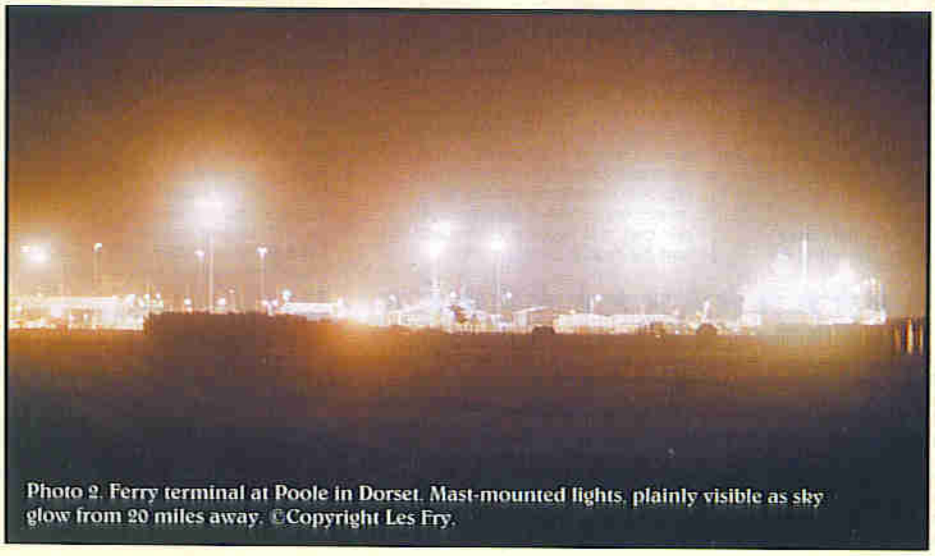


Photo 2. Ferry terminal at Poole in Dorset. Mast-mounted lights, plainly visible as sky glow from 20 miles away. ©Copyright Les Fry.

The Effect of Light Pollution

For professional astronomers, light pollution with low-pressure sodium vapour lamps is less of a problem compared with the effect of high-pressure sodium lamps. The familiar orange colour of low-pressure sodium vapour is in fact mainly provided by a doublet of lines at 589nm and 589·5nm – so a narrow band filter which absorbs these wavelengths can remove most of the problem. Where, however, the source of light is a high-pressure sodium lamp with a broad colour spectrum, the problem cannot be improved by use of such filters.

On a light technology basis, however, the high-pressure sodium source is much more compact and the light output is more easily controlled, e.g., directed downwards. There are thus competing arguments for and against each type of lighting. For the general public, however, both types of light – inappropriately used can lead to adverse light pollution.

With the spread of urban sprawl over large tracts of the UK, it is increasingly difficult to escape light pollution. One of the basic tests for light pollution is to check whether street-lights are visible when looking down on them from a higher level, e.g., a hill or from an aircraft. Invariably, such lights are usually visible from above.

The campaigns for Dark Skies being implemented in various countries are not just about installing lights that point downwards – it is about reassessing aspects of the use of lighting in general. If for example a breakthrough in technology led to a dramatic improvement in luminous efficiency, should this lead to utility lighting being three or four times brighter? There are very good arguments for providing adequate levels of illumination at night, instead of the highest intensity technology will allow. There are many instances where an excess of light is more of a hazard than a help.

A good example of 'adequate' light levels are to be found at airports where the need for illumination of access roads, terminal buildings, and landing and runway lights are balanced so that relatively low levels of illumination are used in safety-critical systems.

There is also criticism of the wide availability and thoughtless use of so called security lighting where very bright xenon arc-lighting is used to illuminate frontages of buildings – often isolated houses in the country. In the parlance of 'Dark Sky' campaigners these are called 'insecurity lights'.

Questions are being asked whether such grand illumination actually affords security or is an encouragement to theft and vandalism. Also, the high levels of illumination are probably counter productive. Most crimes are committed in daylight where thieves can see what they are doing.

The topic of crime and lighting is an old one. In the Victorian era, it was claimed that every single new street lamp would lead to the demise of a policeman. At the very least, security lights need to be implemented so that adequate levels of illumination are produced. Some levels produced by security lighting are considerably in excess of minimal levels. There are instances now where drivers at night can be temporarily blinded by bright lights of premises near the roadside.

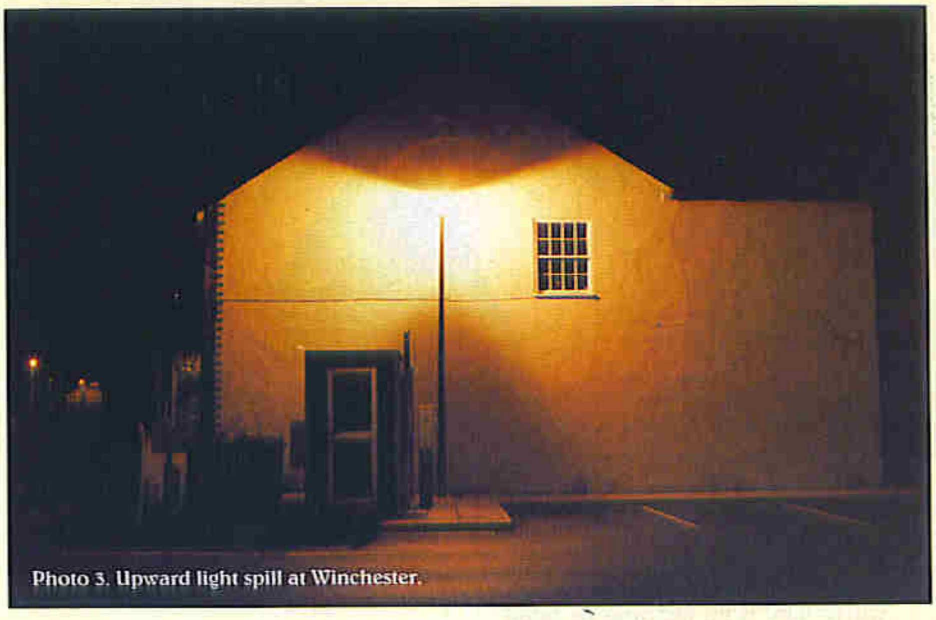


Photo 3. Upward light spill at Winchester.

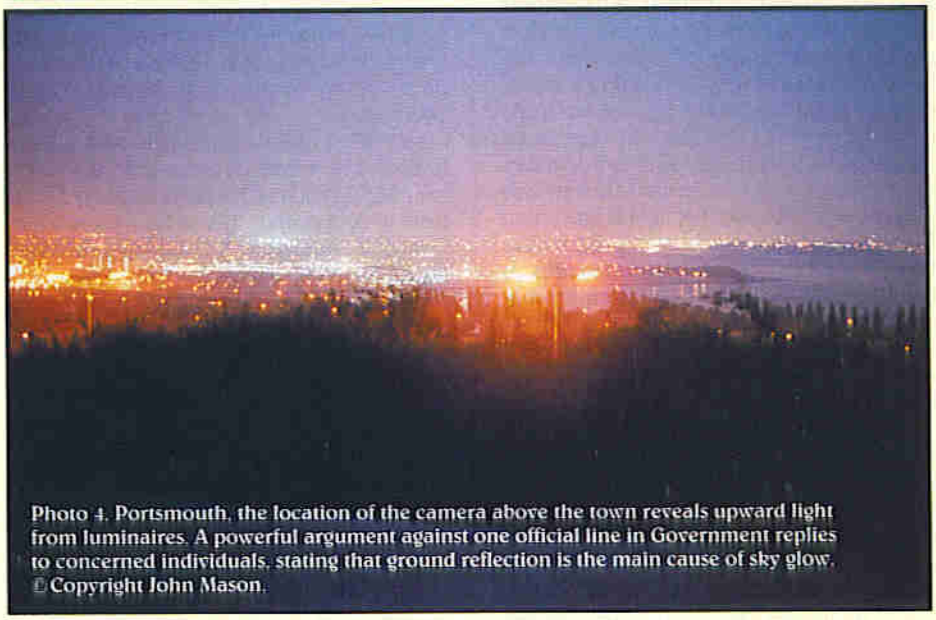


Photo 4. Portsmouth, the location of the camera above the town reveals upward light from luminaires. A powerful argument against one official line in Government replies to concerned individuals, stating that ground reflection is the main cause of sky glow. © Copyright John Mason.

Psychological Loss

With the growth of urbanisation, the benefits of a more ordered, more comfortable life style has been associated with some very definite losses. In the UK there has been the consistent loss of forest cover – a loss which is only appreciated in the quiet depths of what forest spaces still remain. There has been an increase of noise pollution into our lives – such as car and house alarms being accidentally set off, adding to the frustration of everyday life. There is also the loss of the 'Dark Sky' – a more subtle loss perhaps but one with a deep psychological impact.

In today's society, however, part of the myth of the consumer culture is that everything worth having has to be paid for. A gaze at the stars costs nothing yet it can be a source of great stimulation and a wonderful point of contact to the stars and galaxies of the universe and the planets, meteors and comets of the solar system. With all that we know, or are beginning to know about the universe, gazing at the stars is an excellent way to remind ourselves of the almost limitless dimensions of the Cosmos.

We should all have quality 'Dark Sky' memories. Mine are from the August skies of Helmsdale in Sutherland – looking east high above the Moray Firth into the flight path of the Perseid meteors as they graze the upper atmosphere and travel a last few thousand miles of their long pilgrimage around the solar system. Overhead high above the faint shape of the Milky Way wound like a giant serpent in the sky. The memories are still fresh and hopefully will last a lifetime. Usually every adult will have a clear memory of their 'best ever' view of the night sky. The loss of such experiences to present and future generations is very much to be regretted.

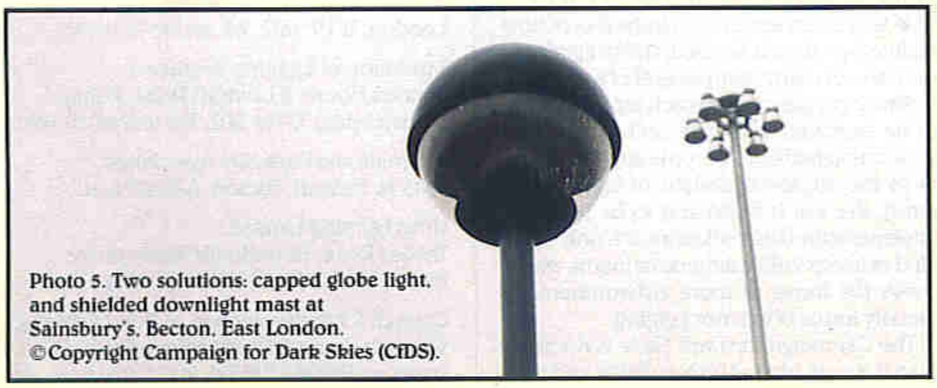


Photo 5. Two solutions: capped globe light, and shielded downlight mast at Sainsbury's, Becton, East London. © Copyright Campaign for Dark Skies (CfDS).

A Simple Code of Lighting Conduct

Part of the argument put forward by Dark Sky groups is to save energy by preventing projecting it skyward in the first place. An important development has been the production by the Institution of Lighting Engineers of *Guidance Notes for the Reduction of Light Pollution*. This guidance is relatively straightforward and is very much a commonsense approach.

Sky Glow is the official phrase for light pollution caused by the scattering of artificial light by dust particles and water droplets in

Photo 6. Southampton Parkway Station. Full cut-off lamps installed to prevent glare to train drivers. Camera position shows effectiveness of luminaires: not visible in picture. ©Copyright R. Arbour.

the atmosphere. Levels of light pollution will also be influenced by levels of atmospheric pollution and prevailing weather conditions. Light pollution can be of a very direct nature, e.g., where light from factories or retail premises manifests as a nuisance to people's homes at night. As part of the guidelines, it makes sense to switch off lights when not required. Infra-red security lighting is highly effective when used with, for example, closed circuit TV cameras. The blackest night scene can be made to appear as light as bright day. Also, light should be directed downwards whenever possible, so that light is prevented from escaping upwards. However, where light is intentionally projected upwards to buildings, care should be taken to ensure that unwanted light spill is minimised.

The greatest problem comes with the poor design of conventional downward illumination such as streetlights. Many domestic exterior wall lights are nothing more than a glass globe – most of the light will be radiated vertically. With use of appropriate reflectors and baffles, light spill can be avoided and higher light levels provided where light is required. In the UK, Urbis Lighting has introduced a range of energy efficient lighting which minimises glare, eliminates upward light and minimises light spill.

A simple and effective way to reduce light pollution is to only switch lighting on when it is required. This can be easily achieved using passive infra-red (PIR) detectors coupled to a timer circuit. Invariably such units include a light level sensor so that operation is automatically inhibited during daylight hours. PIR lighting control is available in the form of a self-contained unit, which can be added to existing lighting equipment. Lighting equipment, with integral PIR lighting control, is also available. Using PIR lighting control will turn lighting on, for a predetermined period, when people are in the area to be illuminated. Use of such a control device is ideal for commercial and residential parking areas, loading areas and walkways. The benefits, other than reducing light pollution are reduced energy consumption, longer lamp life and the deterrent factor for potential thieves and vandals.

The choice and location of lighting equipment is important:

Use the lowest level of illumination necessary to achieve adequate illumination; too high a level of illumination can make matters worse by dazzling people (a 500W halogen floodlight used to illuminate a domestic porch is excessive – use a 150W (or less) unit instead).

Floodlights should be installed as high as possible, pointing downwards; installing them low down at a shallow angle will dazzle people and result in unwanted light overspill.

Instead of using a single light with a high level of light output it is better to have a number of lights, each with a proportionally lower level of light output. This gives a more even level of illumination, thus reducing shadowing and dazzling effects.

Where it is necessary that an area is not in total darkness, a combination of low level (confidence) lighting controlled by a light level sensor, plus higher level PIR controlled lighting is a far better choice than having high level lighting permanently switched on.

PIR lighting control units should be positioned so that they are only triggered when people are in the area to be illuminated, and not by passers-by or vehicles.

Maplin supply a wide range of lighting control and lighting products which, when appropriately chosen and properly installed after careful planning, can be used effectively to provide lighting where and when it is needed, and without causing unnecessary light pollution.

Exercising Responsibility

The environmental arguments for a reduction in light pollution are self-evident. It is, however, a question of priorities. The problem with excess carbon dioxide emissions could lead to instabilities of climate which will dominate future environmental agenda. Population growth is another immanent pressure which is making its presence felt. These are major 'headline' issues.

It will be an increasing challenge, however, to use all kinds of technology in a responsible way as understanding improves of how technology should be used. Utility lighting is only one of many components of a complex technology jigsaw, where each aspect requires to be exercised with care and thought. As solutions to problems become apparent (such as in the improved designs of lighting systems), the will is beginning to be found to implement the better solutions. It is only some kind of irresponsible attitude or inertia which resists the move to more environmentally friendly forms of exterior lighting.

The Campaign for Dark Skies is no more than the exercising of responsibility and consideration, in an area which it has been recognised for many years that little thought has been applied.

It has been an important indication, however, of the responsible approach taken by Dark Sky campaigners. Whether it is an encounter with a local supermarket manager, or a sports complex, or a county council, it has always been the case that a tolerant but committed approach brings the best results. Once individuals and organisations appreciate what is involved in reducing light pollution levels, then they are generally only to pleased to co-operate. People do not generally need convincing about self-evident environmental factors. They do initially need them to be brought to their attention. An idealistic, intolerant approach, however, will be met usually by equally stubborn resistance.

In a rural setting, there is increased identification with the 'rightness' of a Dark Sky. Many schemes to introduce high levels of night-time illumination to country areas have met with strong opposition from groups such as the Council for the Protection of Rural England.

Those getting involved with Dark Sky campaigns need not necessarily be professional astronomers. In the USA, for example, the Board of Directors of the International Dark-Sky Association consisted at one stage of a professional astronomer, a business woman, a science writer, a public relations expert and a lighting engineer. This reflects the general interest that such campaigns generate. For those becoming involved, however, in a campaigning role, it is important to be well versed in appropriate details so that correct advice and comments can be given.

Sky glow is now a part of 20th century society and will surely be with us into the new millennium. Major conurbations such as Phoenix Arizona can be seen 100 miles away; the sky glow from Los Angeles is visible from an aircraft at a distance of 200 miles. There are good safety arguments for providing adequate light levels in public places and for vehicle transport systems. However, this can be achieved without the creation of light pollution.

There has been a move in the USA to establish so called 'Dark Sky preserves' – areas which are protected against unwanted illumination. One such area was recently set up in an area around lake Hudson. While this is one way of guaranteeing a Dark Sky area, it does not deal with the pressing problem of the spread of sky glow, from one end of the developed world to the other.

Useful Addresses:

Campaign for Dark Skies,
British Astronomical Association,
Burlington House, Piccadilly,
London, W1V 9AG. Tel: (0171) 734 4145.

Institution of Lighting Engineers,
Lennox House, 9 Lawford Road, Rubgy,
Warwickshire, CV21 2DZ. Tel: (01788) 576492.

International Dark-Sky Association,
3545 N. Stewart, Tucson, AZ 85716, USA.

Urbis Lighting Limited,
Telford Road, Houndmills, Basingstoke,
Hampshire, RG21 2YW. Tel: (01256) 54446.

Council for the Protection of Rural England,
Warwick House, 25 Buckingham Palace Road,
London, SW1W OPP. Tel: (0171) 976 6433.

LEDs LIGHT EMITTING DIODES AND THEIR APPLICATIONS

Part One – First Principles

By Andrew Chadwick B.A., C.Eng., M.I.E.E.

The development of the light emitting diode (LED), in the 1970s was a result of research into solid-state devices for the production of light for use with optical fibres. However, for the average electronics hobbyist, the LED is probably more familiar in its role as an efficient and reliable replacement for filament lamps in panel indicators, or as the basis of the seven segment display. More recently the infra-red LED has also become commonplace, due to its use in the many remote control units for home entertainment. This series explains how LEDs work, how to choose and use LEDs, and demystifies commonly encountered terminology.

Like many of the products we take for granted, the LED is actually the result of a great deal of technical knowledge and scientific research. The modern LED owes its existence to an understanding of such fields as quantum physics, semiconductor manufacturing techniques and electromagnetic theory. This series can only hope to touch briefly on each of these areas, but hopefully will nevertheless be an interesting and useful introduction to LEDs and their uses.

THEORY OF OPERATION

The theory of electrical conduction in all solids, including semiconductors, is based on the concept of valence and conduction bands. These bands are composed of numerous closely-spaced energy levels that may be occupied by electrons in the material. The conduction band is at a higher energy level than the valence band and the difference in energy between the two is known as the bandgap. The bandgap is a function of the material, some typical values being shown in Table 1.

The chemical symbols used in the materials column represent the following elements: Si-silicon; Ge-germanium; C-carbon; Al-aluminium; P-phosphorus; As-arsenic; Ga-gallium; In-indium; Cd-cadmium and S-sulphur. λg is the wavelength of the light associated with the bandgap.

Material	Bandgap Energy (eV)	Group In Periodic Table	λg (nm)
Si	1·11	IV	1110
Ge	0·66	IV	1880
α-SiC	2·86	IV-IV	434
β-SiC	2·3	IV-IV	540
AlP	2·45	III-V	497
AlAs	2·17	III-V	573
GaP	2·24	III-V	555
GaAs	1·42	III-V	875
InP	1·35	III-V	978
CdS	2·42	II-VI	513

Table 1. Bandgap Energies at 300K.

In a pure semiconducting material most electrons reside in the lower valence band. Only a few gain enough thermal energy to be promoted to the conduction band. These electrons, and the 'holes' they leave behind in the valence band, are free to move and are responsible for electrical conduction. As few electrons reach the conduction band, pure semiconductors have poor conductivities. A simplified view of the situation is shown in Figure 1(a).

Most useful devices rely on 'doping', the introduction of small quantities of impurities, produce 'N' and 'P' type semiconductor materials whose properties are radically different. N-type material has a greatly increased number of electrons in the conduction band and P-type has more holes in the valence band as shown in Figure 1(b). Combining P and N-type material gives the P-N junction, which is the basis of bipolar semiconductor devices such as transistors and diodes.

The LED is also a P-N junction formed in a suitable semiconductor material. When forward biased the electrons in the N-type material are attracted into the P-type material. This increases the concentration of electrons above the normal low level in a P-type material. The excess of electrons diffuses away from the junction and is eventually absorbed by recombination of electrons in the conduction band with holes in the valence band. A similar process occurs in the P-type material.

The electron loses energy during the recombination step which may appear as electromagnetic radiation. It is this phenomenon, known as radiative recombination, which is responsible for the light production in an LED. The overall process is illustrated in Figure 2.

The wavelength of the radiation emitted is inversely related to the bandgap of the semiconductor. In order for an LED to emit radiation in the visible part of the spectrum, the semiconductor must have a bandgap of roughly 2 to 3 eV. Although Table 1 suggests that there are many possible candidates, in practice most are ruled out due to very low efficiency of the radiative recombination process, or difficulties in doping the material.

Most commercial devices are based on III-V semiconductors. Unlike the familiar semiconductors silicon and germanium which are pure elements, III-V semicon-

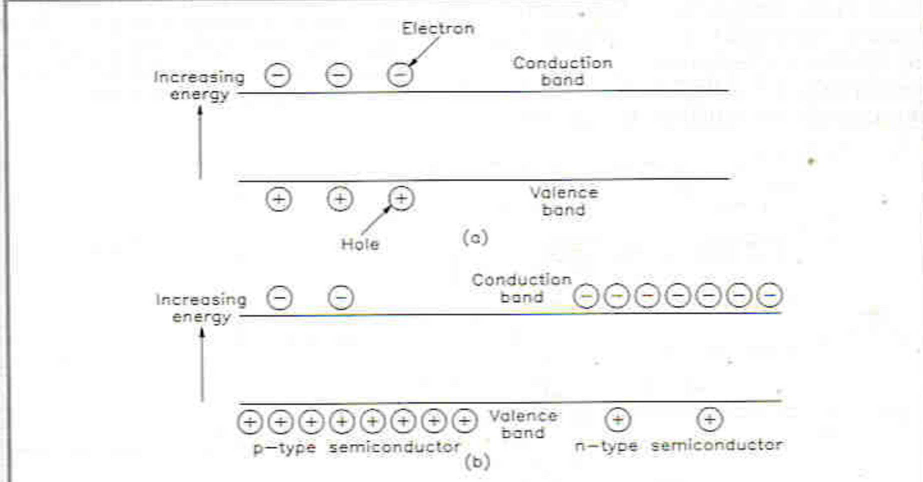


Figure 1. Representation of electrons and holes in (a) Semiconductor; (b) a doped semiconductor.

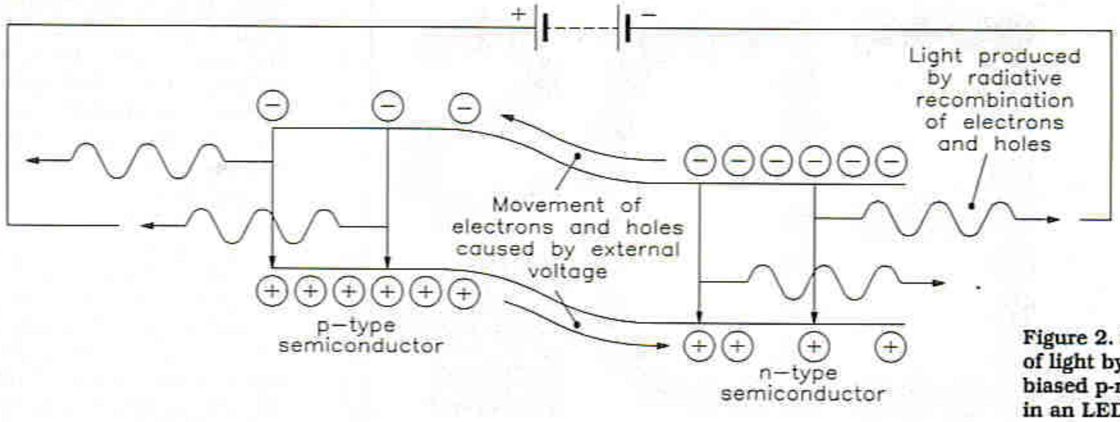


Figure 2. Production of light by a forward biased p-n junction in an LED.

ductors are made from mixtures of elements from Group III and Group V of the periodic table. There must be equal numbers of atoms of the Group III and Group V element as is evident from the formulas of some typical materials AlP, AlAs, GaP, GaAs which appear in Table 1. However, it is also possible to have materials such as GaAs1-yPy which still fulfil this condition but whose properties, including the bandgap, are intermediate between those of GaAs and GaP. The advantage in the case of an LED is that by adjusting the composition, the bandgap, and consequently the colour of light emitted, can be varied. Other mixed semiconductors such as GaAlAs and more recently AlInGaP are also utilised.

MANUFACTURE

Figure 3a shows a cross-section of a typical LED chip which uses $GaAs_{0\cdot6}P_{0\cdot4}$ as the semiconductor material. This is deposited from the vapour phase onto a substrate of pure GaAs or GaP. By controlling the composition of the vapour the composition of the deposited layer can be varied from pure GaAs (or GaP) to the required $GaAs_{0\cdot6}P_{0\cdot4}$, thus smoothing out the lattice mismatch between the crystalline structure of the substrate and that of the $GaAs_{0\cdot6}P_{0\cdot4}$. By diffusing suitable dopants such as selenium and zinc into the surface, N and P-type layers are formed producing a P-N junction. The contact to the P-type region is designed to allow as much light as possible to be emitted from the junction. Light which is emitted downwards will be absorbed if the substrate is GaAs whose bandgap is smaller than that of the P-N junction layer. However, a GaP substrate will be transparent to the emitted light, so a reflective layer on the substrate can return the light upwards.

Since LEDs were first produced, a great deal of research and development work has been aimed at increasing their efficiency. Despite significant improvements as a result of new materials and methods of construction, only a small percentage of the electron-hole recombinations actually result in the emission of a photon of light from the semiconductor surface.

Even if the radiative recombination process is efficient, there remains the fundamental problem of total internal reflection, an effect which is mentioned in most elementary courses on optics. It occurs when a light ray passes from a more dense to a less dense medium, as shown in Figure 4. At small angles of incidence most of the ray passes through the interface and is simply bent or refracted. As the angle of incidence increases more and more of the light is reflected back from the interface. Eventually a point is reached where it is all reflected and none escapes. This angle of incidence is known as the critical angle and its value depends on the refractive indices of the two media. For air and water it is about 50° but for light trying to escape from a semiconductor, with a high refractive index of 3·4, into air, the angle is only 17°. For an unencapsulated LED chip, any light hitting the surface at greater than this angle would be reflected back as shown in Figure 4.

In practice the chip is invariably encapsulated in epoxy which has a refractive index of 1·8 compared to 1 for air. This increases the critical angle at the chip surface to 32 degrees, and more light can escape.

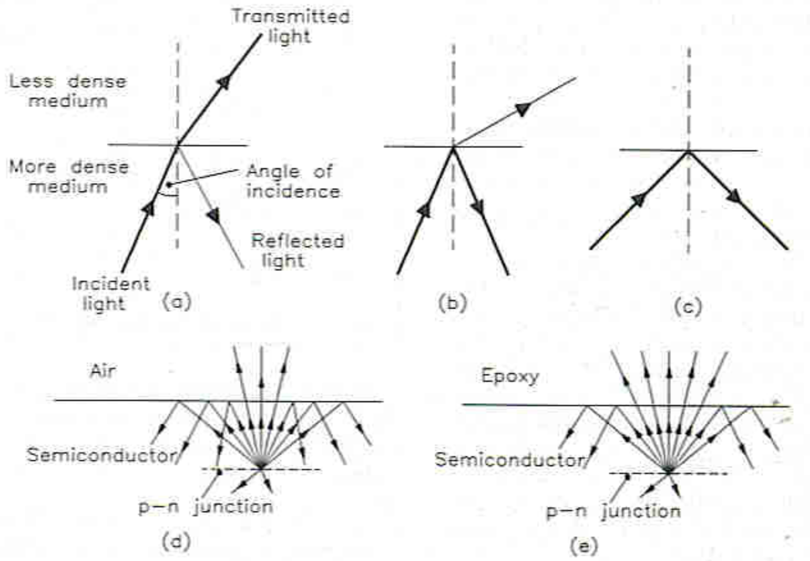


Figure 4. Total internal reflection. (a) Small angle of incidence. Most light transmitted. (b) Increased angle of incidence. More light reflected. (c) Angle of incidence greater than critical angle. All light reflected. (d) In an unencapsulated LED most of the light would be reflected. (e) Encapsulation in epoxy increases the amount of light transmitted.

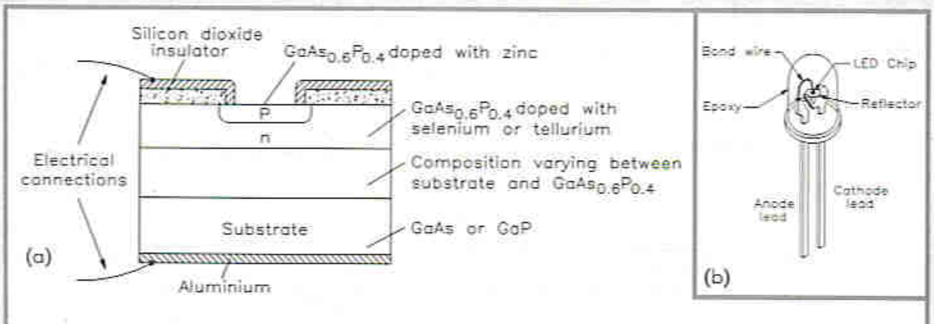


Figure 3. Construction of a typical LED: (a) cross-section of the LED chip; (b) packaging of the chip.

PACKAGING

A typical LED package is shown in Figure 3b. The LED chip is bonded into a cup formed in one of the leads using a conductive adhesive which will allow current to flow to the underside of the chip. The cup acts as a reflector to increase the light output. The other connection to the chip is made via a fine bond wire from the end of the other lead. The whole arrangement is encapsulated in an epoxy package which protects the chip from damage and contamination and also reduces the critical angle, as already discussed. In addition the curved end of the package acts as a lens which has a very significant effect on the beam of light emitted. This is discussed further in the section on viewing angle.

The industry standard method for identifying the leads is to make the cathode shorter. Other additional methods such as a flat or spot on the package may also be used. Note that the lead with the cup formed in it is often, but not invariably, the cathode.

COLOUR, SIZE AND SHAPE

A glance through the optoelectronic section of most component catalogues reveals a bewildering array of LEDs. However, selecting an LED for a particular application is not too difficult once the meaning of the main parameters are understood. Colour, size and shape are perhaps the most obvious and will be covered first.

When LEDs were first introduced it was a question of red or nothing. As already mentioned, it is now possible to produce a range of colours between red and green simply by varying the composition of the semiconductor. Other alternative semiconductor materials have also been developed, including silicon carbide, which has made the manufacture of blue LEDs feasible, although at a price.

The colour of an LED is more precisely specified by the wavelength of light that it emits. (See the section on light for more details). However, the light from an LED is not monochromatic but contains a range of wavelengths as shown in Figure 5. The figure quoted is usually the peak wavelength corresponding to the highest point on this curve. However, because of the spread of wavelengths and the nonlinear response of the eye, the colour of the light will actually appear to be the same as pure light of a slightly different wavelength, known as the dominant wavelength. In most practical applications the difference is not significant. For instance the red LED shown in Figure 5 has a peak wavelength of 635nm and a dominant wavelength of 626nm.

The colour of LED selected is mainly a matter of personal choice. However, 'red' tends to attract attention and is the international colour for indicating that a circuit is energised. 'Green' and 'Yellow' LEDs can appear very similar in colour although they are inherently more efficient.

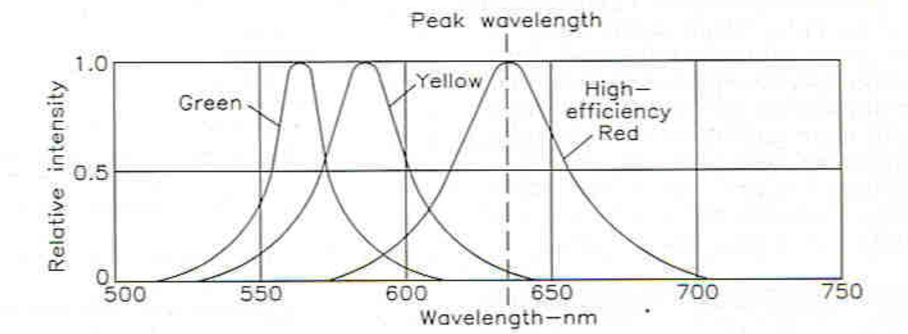


Figure 5. Relative intensity versus wavelength for three typical LEDs. Each LED emits a range of wavelenghts.

Colour Type	Package (D=Diffused, C=Water clear)	LED Diameter (mm)	Peak Wave-length (nm)	Max. Power Dissipation (mW)	Maximum Light output (mcd) I_F=10mA	Forward Voltage (V) I_F=20mA	Forward Current (mA) continuous / peak τ<10μs	Viewing Angle (degrees)	Stock Code
STANDARD EFFICIENCY/BRIGHTNESS TYPES									
RED	D	3	700	120	2·0	2·0	25 / 150	60	WL32K
	D	5	700	120	5·0	2·0	25 / 150	60	WL27E
	D	8	625	105	100·0*	2·0	30 / 150	50	UK21X
	D	10	625	105	100·0*	2·0	30 / 150	50	UK25C
GREEN	D	3	565	105	12·5	2·2	25 / 150	60	WL33L
	D	5	565	105	32·0	2·2	25 / 150	60	WL28F
	D	8	565	105	70·0*	2·2	25 / 150	50	UK22Y
	D	10	565	105	70·0*	2·2	25 / 150	50	UK26D
YELLOW	D	3	590	105	12·5	2·1	30 / 150	60	YY38R
	D	5	590	105	8·0	2·1	30 / 150	60	WL30H
	D	8	590	105	70·0*	2·1	30 / 150	50	UK23A
	D	10	590	105	70·0*	2·1	30 / 150	50	UK27E
ORANGE	D	3	625	105	20·0	2·0	30 / 150	60	WL34M
	D	5	625	105	20·0	2·0	30 / 150	60	WL29G
BLUE	C	3	470	105	5.0*	3·0	50 / 100	20	CJ60Q
	C	5	470	105	5.0*	3·0	50 / 100	16	UL89W
LOW CURRENT TYPES									
RED	D	3	660	100	20·0**	1·65**	30 / 150	60	CJ58N
	D	5	660	100	20·0**	1·65**	30 / 150	60	CJ54J
GREEN	D	3	565	24	3·2**	1·9**	7 / 150	60	CJ56L
	D	5	565	24	3·2**	1·9**	7 / 150	60	UK49D
YELLOW	D	3	590	29	3·2**	1·8**	7 / 150	60	CJ57M
	D	5	590	29	3·2**	1·8**	7 / 150	60	UK50E
ORANGE	D	3	625	26	5.0**	1·7**	7 / 150	60	CJ55K
	D	5	625	26	5·0**	1·7**	7 / 150	60	UK48C
HIGH OUTPUT TYPES									
RED (High)	D	3	625	105	50.0	2·0	30 / 150	60	WL83E
	D	5	625	105	80·0	2·0	30 / 150	60	WL84F
GREEN (High)	D	5	565	105	60·0*	2·2	25 / 150	60	CK40T
RED (Super)	D	3	660	100	90·0*	1·7	30 / 150	60	UK18U
	D	5	660	100	100·0*	1·7	30 / 150	60	UK19V
GREEN (Super)	C	5	565	105	300·0*	2·2	25 / 150	30	CK39N
RED (Ultra)	C	3	660	100	500·0*	1·7	30 / 150	50	UF72P
	C	5	660	100	1000·0*	1·7	30 / 150	30	UK51F
RED (Hyper)	C	5	660	100	3500·0*	1·7	30 / 150	30	UK20W

Notes: *I_F=20mA. **I_F=2mA. maximum reverse voltage 5V@ 10μA except blue LEDs 5V@ 30μA.

Table 2. LED Selection Guide.

The two most common LED packages are the T13/4 (5mm) standard and the T1(3mm) miniature cylindrical types. Larger cylindrical packages up to 10mm in diameter are also available. For those with more radical tastes rectangular, square and triangular packages can be obtained. However, before you get carried away, remember that it is far easier to drill a neat circular hole in a panel!

BRIGHTNESS AND VIEWING ANGLE

The remaining important parameters are luminous intensity, maximum current and viewing angle.

The luminous intensity or brightness of an LED or indeed any light source is measured in candelas (abbreviated to cd). Not surprisingly the luminous intensity is roughly proportional to the LED current and so is normally quoted at a particular current, often 20mA. The full data sheet for the LED will probably include a graph of luminous intensity versus current. A typical specification might be 8mcd at 20mA, mcd being the abbreviation for millicandela. Normally a maximum current is specified for the LED above which damage will occur. This sets a limit on the increase in brightness that can be obtained by simply increasing the LED current.

If brightness is essential then the only alternative is to use an LED with a better specification. In catalogues these are often called high brightness, super-bright or high efficiency (HE) types and have light outputs of up to a few candela! Whatever the name, the principal is more light for a given current or, in other words, greater efficiency. Unfortunately this can only be obtained by tighter manufacturing control or investment in new techniques both of which result in increased cost.

When comparing the light output of LEDs it is obviously important to make sure that both are specified at the same current. Another factor which can be even more misleading is the viewing angle.

Not surprisingly the intensity of an LED depends on the direction from which it is viewed. An LED is brightest when viewed along its axis and appears less bright the larger the angle and direction of view away from its axis. This information is summarised on a data sheet in the form of a graph of luminous intensity, relative to the value on axis, versus angular displacement from the axis as shown in Figure 6. The single figure quoted for luminous intensity is the maximum axial value. The angle between the directions where the intensity has fallen to half the maximum value is known as the viewing angle and is often included in the data in a catalogue. Typical figures range from 5° to 100°. There is at least one manufacturer who uses a parameter known as the 'full' viewing angle. Although the definition of this angle is unclear, it appears to be a lot larger than the viewing angle defined above. Unfortunately it is often mistakenly quoted in catalogues as the viewing angle. This can be very misleading when comparing LEDs from different manufacturers.

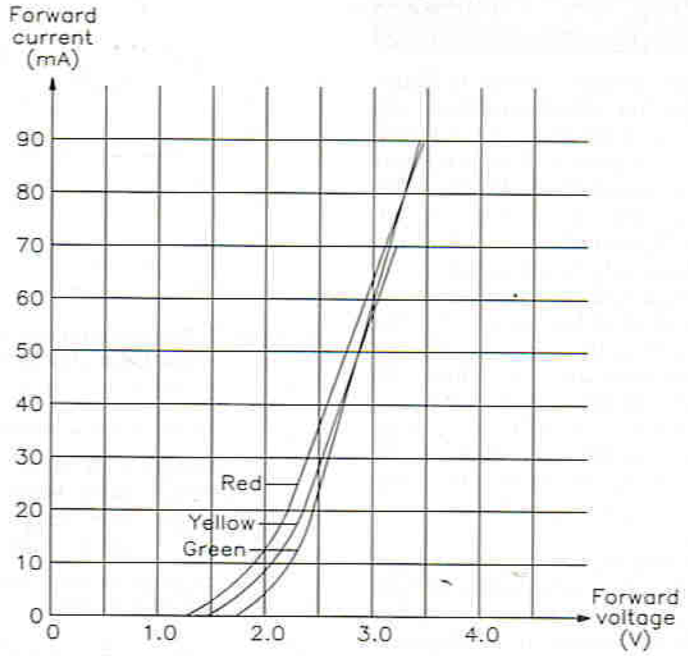


Figure 7. Typical characteristic curves for foward biased LEDs.

The effect of viewing angle on luminous intensity can be described fairly simply. An LED with a small viewing angle will have its light output concentrated in a narrow beam and so the luminous intensity will be far greater than that for an LED with a large viewing angle, even though the amount of light might be identical. An LED with a small viewing angle is acceptable or even desirable for some applications but if used for, say, a panel indicator it would be virtually invisible when viewed from the side.

To a large extent the viewing angle is determined by the epoxy package. The curved end of the familiar round package acts as a lens, and the viewing angle can be varied over quite a wide range simply by changing the curvature of this lens, or its distance from the chip. For even wider viewing angles, a diffused epoxy is used which scatters the light in the same way as a diffuser on a domestic lamp. Note that both clear and diffused lenses can be either tinted or uncoloured. This does not affect the viewing angle but may change the colour slightly, and more importantly shows what colour the LED will be when lit.

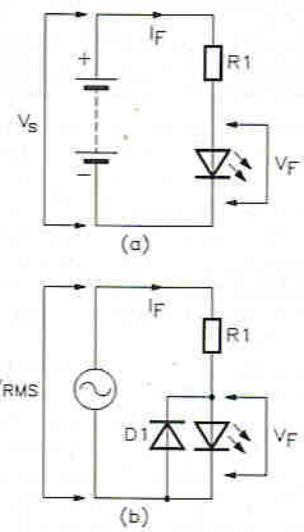


Figure 8. Circuits for operating LEDs.
(a) Using a d.c. supply.
(b) Using an a.c. supply.

As with all semiconductor parameters there is a large tolerance on the luminous intensity. The figure quoted is usually the typical value. The full data sheet will show that the minimum value could be as low as one third of this. This could be significant if trying to match the intensity of a row of LEDs. Fortunately the response of the eye, like the ear, is logarithmic and so a ratio of luminous intensity of up to 2:1 is not noticeable.

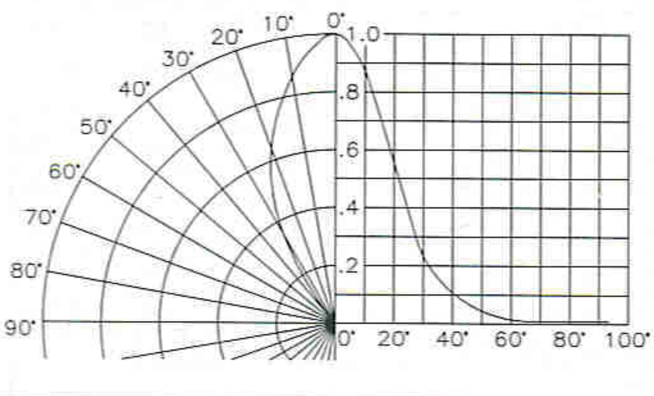


Figure 6. Relative luminous intensity versus angular displacement. The graph represents the data in polar form on the left and conventionally on the right. The viewing angle for this LED is 45°.

Current Limiting Resistor Chart

LED Forward Current (mA)

Supply Voltage (V)	2mA		5mA		10mA		20mA		30mA		40mA		50mA	
	DC	AC	DC	AC	DC	AC	DC	AC	DC	AC	DC	AC	DC	AC
5	1,500	750	600	300	300	150	150	75	100	50	75	38	60	30
9	3,500	1,750	1,400	700	700	350	350	175	233	117	175	88	140	70
12	5,000	2,500	2,000	1,000	1,000	500	500	250	333	167	250	125	200	100
15	6,500	3,250	2,600	1,300	1,300	650	650	325	433	217	325	163	260	130
18	8,000	4,000	3,200	1,600	1,600	800	800	400	533	267	400	200	320	160
24	11,000	5,500	4,400	2,200	2,200	1,100	1,100	550	733	367	550	275	440	220
36	17,000	8,500	6,800	3,400	3,400	1,700	1,700	850	1,133	567	850	425	680	340
115	56,500	28,250	22,600	11,300	11,300	5,650	5,650	2,825	3,767	1,883	2,825	1,413	2,260	1,130
230	114,000	57,000	45,600	22,800	22,800	11,400	11,400	5,700	7,600	3,800	5,700	2,850	4,560	2,280

The values given in the table represent the value of resistor in Ohms that is required to provide the required series current at a particular voltage. Supply voltage is given in the left-hand column, currents in the top of the table, and V_F is taken to be 2V.

Table 3. Current limiting resistor chart.

ELECTRICAL CHARACTERISTICS

Some typical characteristic curves for forward biased LEDs are shown in Figure 7. They behave in a similar manner to a Zener diode with very little current flow until a 'knee' or 'avalanche' voltage is reached, after which current increases rapidly. Note that the analogy with Zener diodes only applies to the electrical behaviour, the mechanisms being completely different.

The 'knee' or 'avalanche' voltage varies with the colour of the LED, reflecting the increase in bandgap. For red, yellow, green and blue LEDs typical figures are 1·8V, 2·0V, 2·2V and 3·0V. Above this 'knee' voltage LEDs behave as though they have an internal resistance of a few tens of ohms.

When reverse biased the LED again behaves like a Zener diode with no current flowing until a voltage of typically 5V is reached, at which point the junction breaks down. Further increase in voltage will cause a large, potentially destructive increase in current.

Due to the nature of their characteristics LEDs cannot be simply connected to a power supply in the same way as a filament lamp. Some means must be incorporated to limit the current through the LED to the required value, the usual method being a series resistor. Figure 8(a) shows a suitable circuit for a DC supply. The recommended current through the LED can be found from the data sheet or catalogue and is normally about 20mA for a standard LED. The voltage across the LED at this current is also often quoted. If not then a value of 3·0V for blue LEDs and 2·0V for any other colour is a good approximation. The value of resistor R_1 is then given by the formula:

$$R_1=\left(\frac{V_S-V_F}{I_F}\right)$$

where: V_S is the supply voltage
V_F is the LED forward voltage
I_F is the LED forward current

A typical example would be for a red LED rated at I_F=20ma, driven from a 12V supply. The forward voltage of the LED is stated as 2V. Using the equation above just plug in the values to find the minimum value of series resistance that can be used.

$$R_1=\left(\frac{V_S-V_F}{I_F}\right)\ R_1=\left(\frac{12-2}{0{\cdot}020}\right)=500\Omega\ \text{(min)}$$

The nearest preferred value to this would be 560Ω. The power rating of the resistor should be at least:

$$P=I_F I_F R_1 \text{ or } P=I_F^2 R_1$$

In the above example where the resistor required was found to be 500Ω (560Ω nearest preferred value), the resistor must be able to withstand a power dissipation of:

$$P=0{\cdot}020^2\times500=0{\cdot}2W$$

A ¼W resistor would therefore be adequate.

In the case of an AC supply the LED must be protected from reverse voltages that exceed the reverse voltage rating of the LED, which is typically 5V, but may be as low as 3V. Figure 8(b) is an acceptable arrangement. The parallel diode D_1 conducts on the half cycles when the LED would otherwise be reverse biased. This arrangement is preferable to a series diode as the leakage current of the protective diode could be the same order as that of the LED, resulting in a significant voltage drop across it.

Calculation of resistor R_1 is now more difficult. As the LED is only lit for roughly half the time it must have a higher intensity during the on time in order to give an average brightness comparable with the DC case. An approximate value for R_1 can be found by using the equation:

$$R_1=\left(\frac{V_{RMS}-V_F}{2I_F}\right)$$

where: V_{RMS} is the RMS supply voltage
V_F is the DC value of the forward voltage
I_F is the DC value of the forward current

If, for example, you need to power an LED from a 30V AC supply you would require a series resistor of value:

$$R_1=\left(\frac{30-2}{2\times0{\cdot}020}\right)=700\Omega$$

700Ω is not a preferred value, so the closest match to this would be 750Ω.

This equation is fairly accurate as long as V_{RMS} is at least five times V_F. Although the peak forward current may seem to exceed the maximum rated current of the LED, no damage will result as the average current is quite small. For further details see the section on pulsed operation of LEDs in part three of the series. The power rating of R1 is best estimated as:

$$P=\left(\frac{V_{RMS}\times V_{RMS}}{2\times I_F}\right) \text{or } P=\left(\frac{V^2_{RMS}}{R_1}\right)$$

When reading values from the table always take the nearest preferred value, larger than the calculated resistance. Taking a smaller value may supply currents exceeding the maximum allowable forward current for the LED. Lists of preferred values can be obtained from component catalogues etc.

NEXT MONTH

Next month we continue the discussion with other types of LEDs including multicoloured, flashing and constant current LEDs, together with LED bar, 7-segment and alphanumeric displays.

REFERENCES

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J Wilson, J. F. B. Hawkes – *Optoelectronics.*
Hewlett Packard – *Optoelectronics Designer's Catalogue.*
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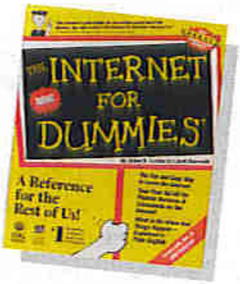
New Books

The Internet For Dummies

by John R. Levine & Carol Baroudi

The Internet, also known as the Net, is the world's largest computer network, or Net. In fact, Internet is not really a network but a network of networks– all freely exchanging information. Internet is probably the most open network in the world with tens of thousands of computers providing facilities that are available to anyone who has Net access.



Most networks are very restrictive in what they allow users to do, and require specific arrangements and passwords for each service. Although a few pay services exist, and no doubt more will be added in future, the vast majority of Internet services are free for the taking.

For the beginner to Internet, who is unsure how to take advantage of this massive network, this book provides a vital reference that will enable the user to swap e-mail, conversation, software, and much more from around the world. The friendly approach – as with all books in the Dummies series – will help the novice cut the networking jargon and quickly get to the best resources the Internet has to offer.

The book is designed to be a reference book, and is made up of six parts – each part is self-contained and can be read separately. A highly recommended book from the Dummies series that will be invaluable to all Internet users.

1993. 380 pages. 230 x 188mm, illustrated.

Order As AN17T
(Internet For Dummies) ***£17.99 NV***

Principles of Transistor Circuits

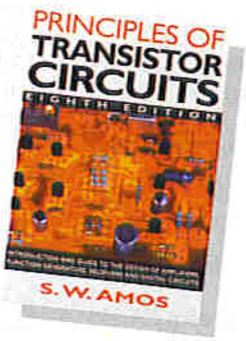
by S. W. Amos

Although integrated circuits (ICs) have widespread applications, the role of the discrete transistor is undiminished whether used in building blocks or as practical solutions to design problems. This is particularly relevant when appreciable power output or high voltage is required.

For over thirty years, the author has provided students and engineers with an authoritative text on discrete devices, that they could rely on, to keep them at the forefront of transistor circuit design. The book is written in a clear and detailed way, and includes the very latest devices such as laser diodes, Trapatt diodes, optocouplers and GaAs transistors, as well as the latest techniques for line output stages and switch mode power supplies. This latest edition includes circuit techniques covering current-dumping amplifiers, bridge output stages, dielectric resonator oscillators, crowbar protection circuits, SHF amplifiers in satellite receivers, video clamps, picture enhancement circuits, motor drive circuits in video recorders and camcorders etc., and much more.

There is a basic and thorough introduction to semiconductor physics followed by details of transistors, amplifiers, receivers, oscillators and generators. Appendices provide information on transistor manufacture and parameters as well as transistor letter symbols.

1994. 400 pages. 215 x 134mm, illustrated.



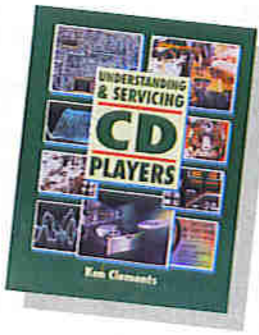
Order As AN16S
(Principles Trans Cct) ***£17.95 NV***

Understanding & Servicing CD Players

by Ken Clements

The CD player has been around for some years now, but the actual servicing of the players has tended to cause much frustration. Many of the earlier models had numerous tweaks, whereas the latest models have hardly any. Mechanical problems being particularly difficult to put right. CD players are not necessarily the beast that they can appear to be, requiring a certain approach and an element of confidence.

The book provides a very readable understanding of CD technology, and will supplement the relevant service manual for the CD that requires servicing. The text takes a problem solving approach with numerous examples, circuit diagrams and line drawings. Engineers who need to achieve a better understanding of CD technology will find this book an essential tool for fault diagnosis, adjustment and repair. The profusely illustrated text covers both the mechanical design and the ICs used within a CD player, and gives a thorough grounding in the basic principles of CD technology. All the various servo systems are discussed as are the decoder, system control and power supplies.



Written specifically with service technicians and engineers in mind, the book will also be invaluable to the audio enthusiast, as it is designed to be a bench-side companion and guide to the principles involved, in repairing and adjusting CD players.

1994. 210 pages. 253 x 193mm, illustrated. Hardback.

Order As AN12N
(U/Stnd & Service CDs) ***£25.00 NV***

First Year Engineering: Information Technology & Systems

by D. C. Green

This book provides a comprehensive introduction to probably the three most important topics covered by first year students on technician courses. Students on courses leading to engineer status will also find the book invaluable. The book is designed to provide a fundamental understanding of information technology (IT), microelectronic systems and communication systems, and includes all the content of the BTEC First units required for these topics. Also, these units are a requirement for students who wish to continue with further study in electrical, electronic, communication and computer engineering. The book will also suit those who are new to these subjects or would like to acquire a general introduction to them.

The clear, concise text uses a simple non-mathematical approach, and along with 200 line drawings and exercises, produces a book that is easy to understand and read. The first five chapters cover the contents of the Information Technology unit 2864B and includes IT, digital computers, input/output devices, software, IT in the office. The following three chapters meet the requirements of the Microelectronic Systems unit 2869B and discuss analogue and digital signals, microelectronic systems, assembly language programming. The rest of the book follows the requirements of the BTEC Communications Systems unit 2872B and includes information transmission, telephone networks, data communications, radio and television systems.

A highly recommended book from a well respected author who has spent many years in related industries and teaching.

1994. 260 pages. 245 x 189mm, illustrated.

Order As AN19V
(Info Technology Syst) ***£10.99 NV***

An Introduction to Light in Electronics

by F. A. Wilson

Light is very much taken for granted by us all, yet most of us know very little about it – even the experts are still struggling with the many gaps in their knowledge. Not so long ago, it was believed that since light travelled through space there must be a medium called the either. Today we are a little wiser, we now know much more about the electromagnetic wave, such as how to generate it, control it and use it, yet when it comes to light waves there are still some gaps in our knowledge of the complete process. However, this book sets out to improve our understanding of what we do know, especially as it now affects modem electronics, since light has become a very important part in the communications industry.

It might be felt that a study of light involves the reader in detailed mathematical analysis, but this has been avoided and nothing more than an understanding of basic mathematics is required. The book has been written with the electronics enthusiast in mind, but experts will find the text an enjoyable and refreshing light read.

1994. 170 pages. 178 x 111mm, illustrated.

Order As AN20N
(Intro To Light/Elect) ***£4.95 NV***

Introducing MAPSAT II

Text by Dennis Butcher and Brian Clark

In 1986 Maplin released the original MAPSAT project, giving an amateur the ability to receive and display weather satellite images, beamed from space back down to earth. Requiring only moderate construction skills the kit proved very popular and many people, having built the MAPSAT receiver and decoder, then went on to build the associated Down-Converter and Aerial projects, allowing the system to be used for receiving Meteosat series transmissions.

THE original MAPSAT kit offered a basic manually tuned VHF receiver with an 8-bit decoder, and satellite passes had to be recorded onto audio tape and then displayed on a monitor via the Frame Store project. For those with the luxury of a computer, the images could be fed into a BBC or Amstrad computer, in real time.

The kit is now nearly 9 years old, and although it has served its purpose of providing a reasonably priced expandable project, the time has come to move on to bigger and better things.

MAPSAT2 is the dawn of a new era in the simple, reasonably priced reception of weather satellite images. The system consists of:

1. A fully synthesised VHF Weather Satellite receiver offering many new features and innovative controls over the old receiver.
2. An interface for converting signals from the receiver to RS232 levels so that a computer can interpret weather satellite images.
3. NESAT software to allow an IBM compatible computer to display and manipulate received images and store them on disk or provide hard copies.

Figure 1 shows a block diagram of the system modules, and the way they interact.

Construction

The receiver comes ready-built and tested, and is housed in a purpose-built case. The controls for the receiver unit are easily accessible from the front panel, and the connections for aerials/interfaces are hidden from view on the back panels. The interface unit is housed in a similar box and usually resides next to, or on top of, the main receiver unit.

Powering the units is achieved by plugging an IEC lead into the back of the receiver unit; an internal power supply does the rest. Power for the interface is derived from the receiver by connecting the two with the lead supplied. The same applies with respect to the data signal – a suitable lead connecting the two units. Both units are rugged by design and as there are no adjustments to be made inside, the cases should never need to be opened, unless returned for repair to the Maplin Service Department.

Installation

One of the main design concepts has been that the units should provide a plug'n'play solution, requiring the minimum of setting up or adjustment. The first requirement for providing a working system is a good aerial. A typical aerial to start with is the VHF Satellite Aerial Kit (LM00A), presented elsewhere in this issue. This type of aerial provides a good all-round (hemispherical) signal coverage

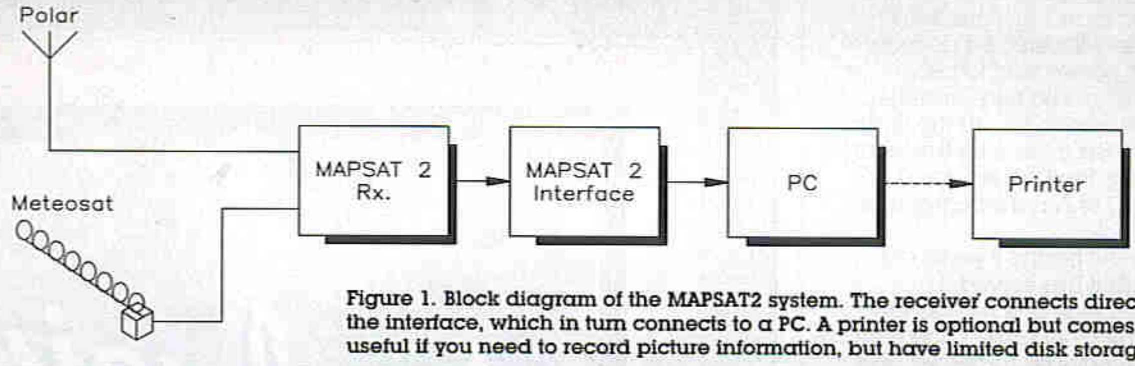


Figure 1. Block diagram of the MAPSAT2 system. The receiver connects directly to the interface, which in turn connects to a PC. A printer is optional but comes in very useful if you need to record picture information, but have limited disk storage space.

(Figure 2), which allows a satellite to be tracked from horizon to horizon, and requires less setting up, when compared with a directional one. Being a lightweight design, a 'Turnstile' aerial can easily be fitted to a chimney mount or to a post if required. Non-metallic objects tend to have little or no effect on the signal reception so, as long as the aerial is about 20 feet from any obstacles and has a good line of sight for passing satellites, there should be no problems. Construction of the aerial kit normally takes in the region of an hour, but if epoxy potting compound is used it tends to take about 24 hours to fully harden.

The length of coax used to connect the receiver to the aerial can make a big difference to the quality of reception. Keeping the length of the cable to less than 10 metres should produce ideal results and keep losses to a minimum. If you need longer cable runs, all is not lost, however, because you might still get away with the extra loss, or in the worst case need to use a preamp. A new preamp kit (LT73Q) published in *Electronics* – Issue 81 (September 94), ideal for this application, has been designed and should you have any problems with signal level or interference, this unit should cure them. Powering the preamp is simple because the MAPSAT2 receiver supplies 12V DC via the coax, just for such applications.

With the aerial in place and the cable run installed, terminate the coax in a suitable plug (FD85G is OK, but discard the screw and solder the inner to the connector centre pin, for a good connection). Connect the lead to the port marked POLAR. This is for POLAR orbiting satellites as opposed to METEOR satellites, which require a directional antenna.

The last item of hardware that needs to be connected is the interface. As mentioned briefly earlier, this is for converting the audio data signals from the receiver into a suitable RS232 level. The RS232 format signals can now be fed into a computer via the serial interface. Software is supplied with the system to allow an IBM compatible PC to receive satellite images. Installing the software in a computer is a fancy-free operation, and requires that the user is able to make a directory and copy

Technical Specification

The specifications for the receiver and interface are as follows:

Receiver	Power requirements:	240V AC (nom.) <1A
	Type:	Triple-conversion superheterodyne
	Inputs:	75Ω (Belling-Lee sockets)
	Final IFs:	10·695MHz, 455kHz
	Receiver coverage:	130 to 140MHz
	Out-of-band attenuation:	Better than 40dB
	Tuning:	Selectable 1kHz & 100kHz stepped microprocessor controlled.
	Outputs:	AF @ 1V Pk-to-Pk into 600Ω +12V DC on aerial socket centre pins (May be changed to +24V DC if reqd.)
	Dimensions:	300 × 280 × 105mm (W × D × H)
Interface	Type:	DSP (digital signal processor)
	Input:	AF @ 1V Pk-to-Pk
	Input impedance:	600Ω
	Output:	RS232 serial format
	Power:	+12V DC at 60mA

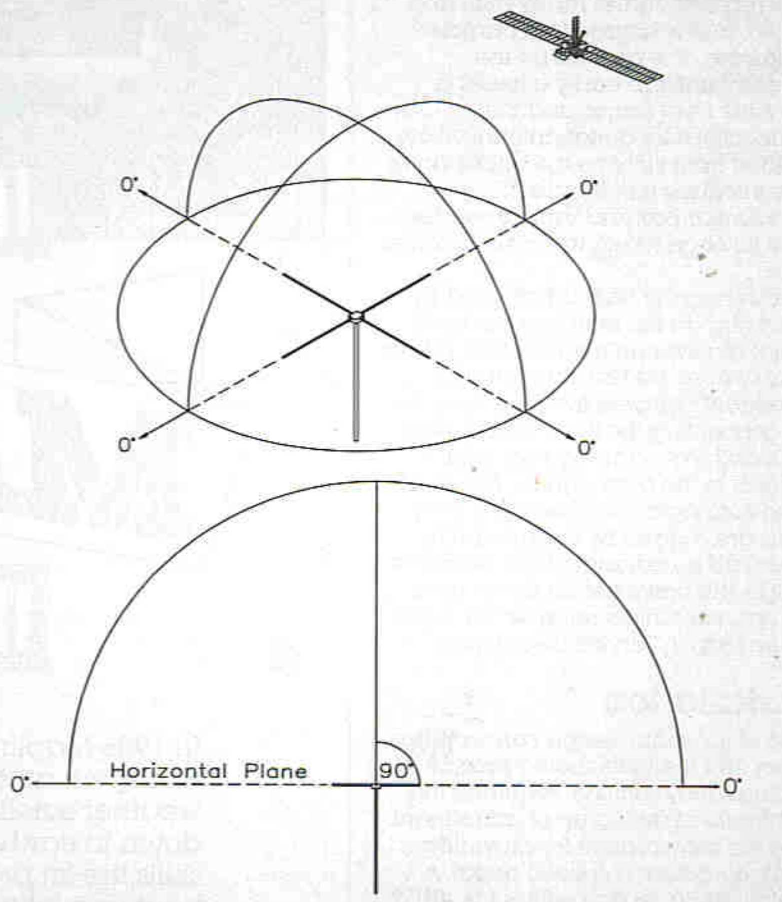
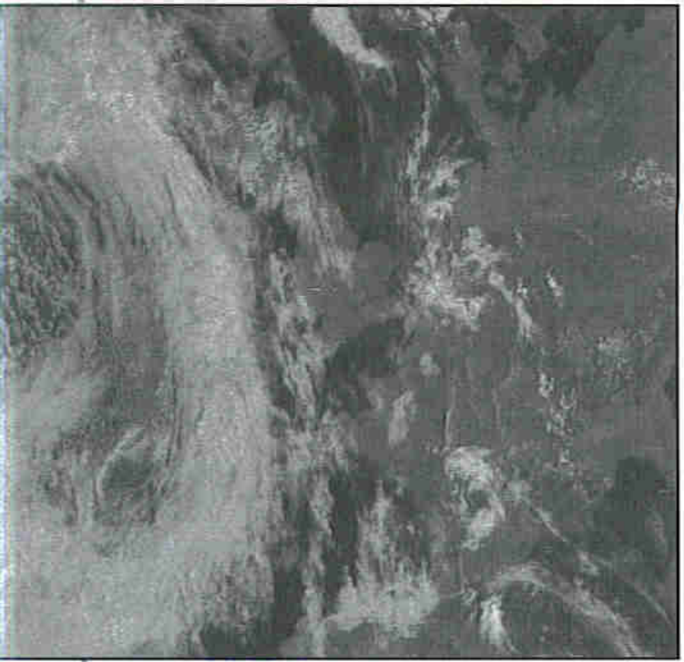


Figure 2. The VHF Crossed Dipole Aerial Kit (LM00A), provides a good horizon to horizon (hemispherical) signal coverage. Construction is simple and normally takes about an hour, requiring only moderate construction skills.



Left: Photo 1a. Taken from the NOAA 9 satellite, a high resolution image of the UK under a blanket of cloud.

Left: Photo 1b. A typical Meteosat image taken using the new Down-Converter available in 1995. Images taken from Meteosat cover the whole of Northern Europe, making them one of the most revealing of all the available images.

Below: Photo 1c. A side-by-side image from NOAA 9. Having both infra-red and visible light images means that during the day you can monitor both, and at night infra-red imaging can be used in high resolution mode.

a couple of files. The program is supplied on a 3½in. disk and contains the program files and a sample animation sequence from Meteosat, showing cloud movement (see later for details).

The program itself runs under DOS and can be made to run under Windows if required. Note that if you intend running the program under Windows you will probably need to write a PIF telling Windows that you need **Video Memory** set to **High Graphics**, otherwise the display will not appear in the correct mode, if at all! Running the program is simple, just change to the NESAT directory and type `NESAT'. Although you will be met with a rather bland opening screen, don't be dismayed, the high-resolution graphics have been saved for the real working parts of the program. It is possible to operate the program from the keyboard or by mouse. Some problems have been caused with incompatible mouse drivers, so you should be aware that if your computer seizes up or crashes when you run the program, it might not be the program!.

You are now ready to go. . . except there probably won't be a satellite in your area at this exact moment, now that you need it! There is, however, a demonstration that can be loaded, and is ideal for at least getting some images onto your screen. Using the TAB key and cursor keys (or a mouse if you have one, and a driver), select the **ANIMATION** menu and then **EDIT ANIMATION.** Select **BACKGROUND** and highlight **'d2.bk1'**, then **OK.** Now repeat the first step but this time select **LOAD**, **'d2.sqn'** and **OK**. The animation sequence should now be loaded up and just requires that you select **ANIMATION** and **RUN.** The screen should now display an animation of Western Europe, part of North Africa and the western end of the Mediterranean. The coastlines are outlined with dotted lines and the cloud can be seen as it rushes and swirls from high pressure to low pressure areas. Note that these pictures are of reduced resolution in order to achieve a higher speed of animation. The received pictures will be of even higher quality, so it is worth persevering and finding a satellite.

Having got fed up with the animation, and pending a satellite passing over, you are now ready to pick up your first live satellite transmission. Information on operating the receiver, and getting the most out of it, is all given in the manuals accompanying the receiver and interface. Suffice to say it is just a matter of following the above installation procedure, setting up the software to receive and tuning to a passing satellite.

The next vital piece of information required, is when the satellites' orbit and their frequencies. Various 'Shareware' programs are available for this, like SatTrak 2·8 (see later).

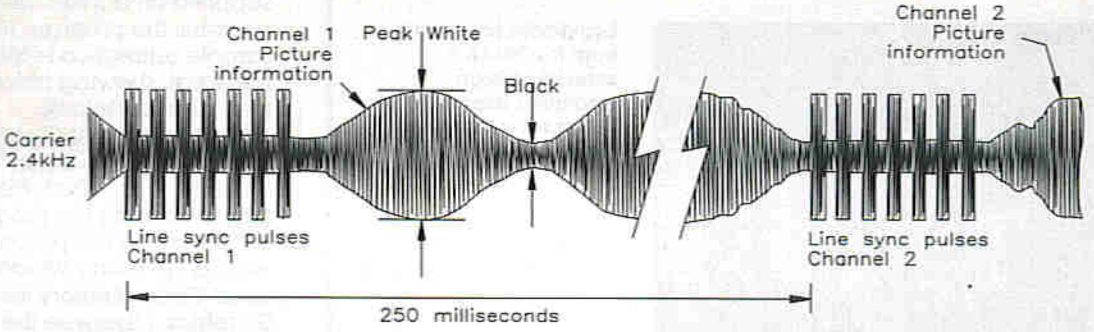
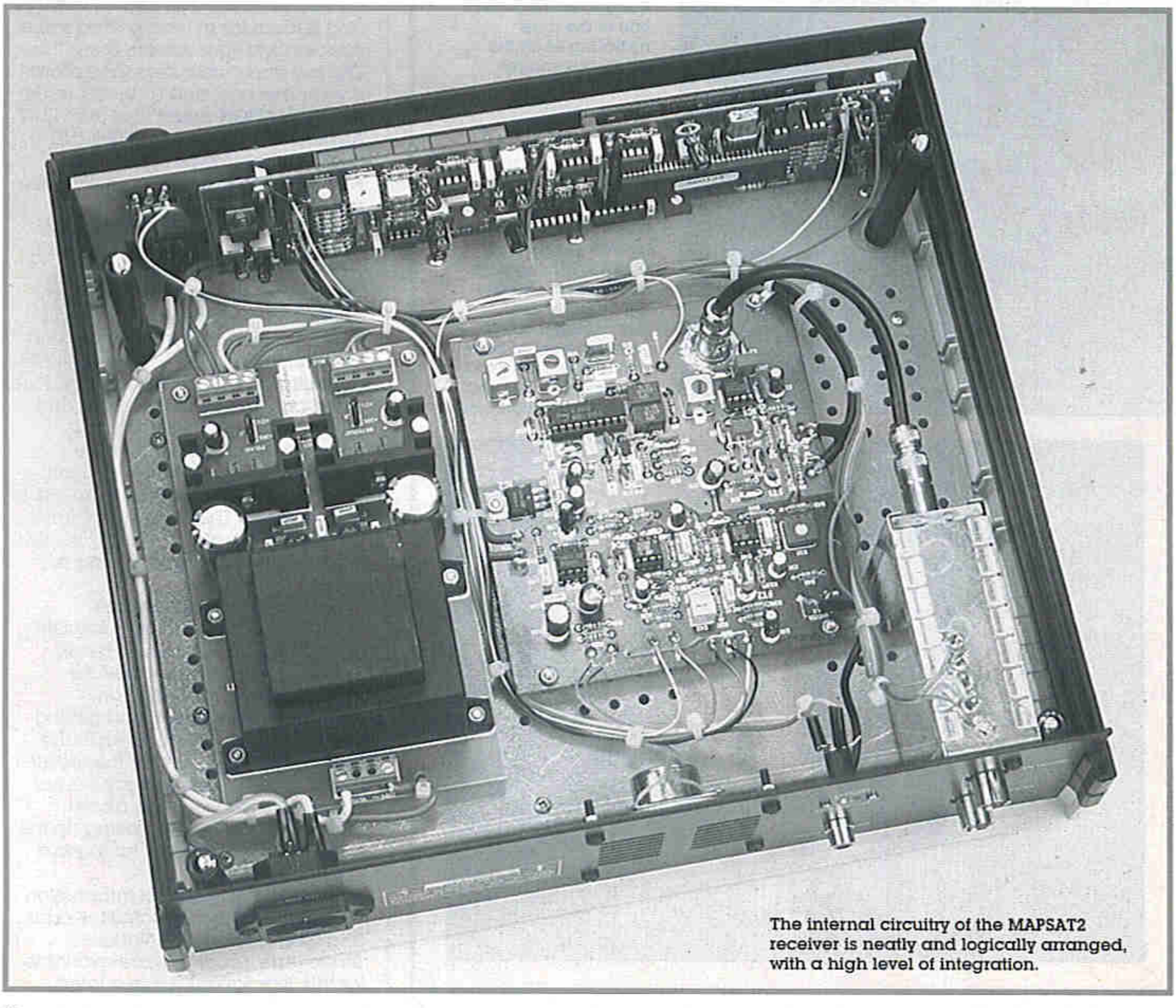


Figure 3. The APT Format signal. The line sync pulses at either side of the picture information give this format a distinctive clip-clop sound. The 2·4kHz carrier can be seen, with the picture information modulated onto it.

The Americans currently operate a number of NOAA (National Oceanic and Atmospheric Administration) satellites. NOAA 9 is the oldest but still gives good images even though the signal seems a little rough lately. Also NOAAs 10 to 12 orbit regularly, with NOAA 14 soon to be launched. There was a NOAA 13 (briefly), but it got lost soon after launch and has never been seen or heard of since! All the NOAAs transmit on either 137·500MHz or 137·620MHz, and include a beacon on 137·770MHz which cannot be decoded but provides an indication that a satellite is passing over. The NOAAs have a very distinctive clip-clop sound with a 2·4kHz sub-carrier and a high-pitched background whistle. This is the sound of the APT format signal, see Figure 3.

The NOAA satellites actually transmit two types of image on WEFAX, side by side. One image is visible light, (obviously not that informative during night hours!), and an infra-red image giving indication of temperatures. Hot objects are shown as black, while warmer objects show up as being white. This makes the seas look black during the daytime, with the land showing up as a lighter colour and the cloud represented by swirly white masses, not too dissimilar to what we see looking out of the window normally. This colour scheme was obviously adopted to make the clouds stand out against the darker sea and land background, to make interpreting the images a little easier. NOAAs sometimes transmit high-resolution

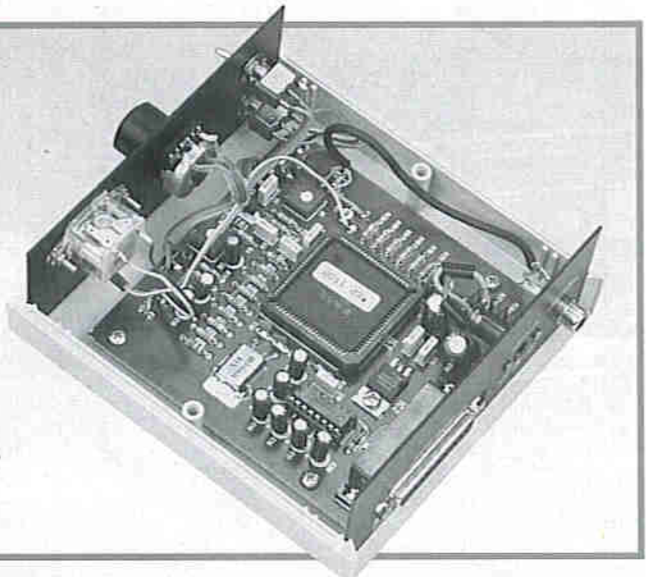


The internal circuitry of the MAPSAT2 receiver is neatly and logically arranged, with a high level of integration.

pictures on 1·7GHz, but reception of these signals would require a sophisticated computer tracking system, in order to follow the satellite pass.

The Russians operate a similar Weather Satellite system using METEOR satellites. METEOR 2s transmit a single picture, either visible light (by day) or infra-red (by night). METEOR 3s transmit images in a similar manner but have the ability to send either normal or high-definition pictures. The transmission format for the images is similar to the NOAA satellites but the synchronisation pulses are at 300Hz which produces a distinctive 'buzz-buzz. . .' sound. METEOR transmissions are usually found on 137·300MHz, 137·400MHz and 137·850MHz. A facility that will be of great use here is the scanning operation. METEORs have a tendency to change between the three frequencies, so if all three are programmed into the receiver and it is set to scan mode it will look at each in turn until a satellite becomes available, at which point it will lock to that frequency until the pass has finished, and it loses the signal. When signal lock is lost the scan will begin again.

Another satellite worthy of mention is Meteosat, which orbits the earth at a height of 36,000km above the equator and is therefore geostationary. Meteosat 5 constantly monitors the weather in our hemisphere, and although its primary users are World Weather Organisations, the transmission is in a similar format to the polar orbiting satellites. As MAPSAT2 stands, it cannot pick up these transmissions but with the addition of a suitable down-converter, in order to bring the 1·6GHz signals into band, there are no problems with receiving the transmission. In fact it has already been done; look out for the Down-Converter when it appears as a project in 1995! To give you a taste of what will be available Photo 1b shows a Meteosat infra-red image of Northern Europe.



Inside the interface unit there is a flat-pack IC, a digital signal processor, that does all the translation from audio to TTL levels. Another IC performs the final translation of TTL to RS232 levels.

On the back of the interface unit are the sockets for power and audio (from the MAPSAT2). A 25-way serial connector for the RS232 levels is also provided on the back of the interface unit.

First Contact

The time has finally come to receive a live picture from space. By using TRAKSAT 2.8, the next usable satellite pass can be calculated, giving the location and signal coverage of each satellite on a map of the world. By supplying the current time you can find out which satellites will be available in your vicinity in the near future. The first satellite to come within range was the NOAA 9, see Photo 1a. The image was received at 09:55 GMT on 25th July 1994 using high-resolution mode. In standard mode it is possible to receive both the visible and the infra-red pictures and display them side by side. In high-resolution mode, whichever type of image is selected, it will expand to fill the whole screen, therefore, you cannot view both at the same time. You can, however, receive and store the visual image and then

The back of the MAPSAT2 receiver hosts the connectors for power, aerials and the interface unit. Power for the interface unit is also derived from the MAPSAT2 receiver, keeping the arrangement simple and compact.

repeat the procedure for the infra-red image.

On the actual image received you can clearly make out the major land masses including the UK in the centre, a depression over the Atlantic and Ireland, Spain, France and Scandinavia. Photo 1c shows a side-by-side visible and infra-red image, again from the NOAA 9 satellite, at 09:40 GMT on 26th July, and shows the different information that can be represented by infra-red imaging.

Operation

The proof of the pudding, as with most things, is in the eating. Using the MAPSAT2 setup after using the original MAPSAT, is like a dream come true. Tuning is made simple with the aid of SEEK and SCAN controls, UP/DOWN frequency buttons for manually tuning, 1kHz and 100kHz stepping; in fact the receiver is similar to a digital car radio with respect to the ease of tuning. A backlit green multi-function LCD display constantly shows the frequency, signal strength and current state of signal lock. In addition, and depending on the current mode of operation, the display will also show other information like memory contents, etc. With the old system, finding the required signal was not always the end of the story as the frequency tended to wander with time. This could be due to the use of a down-converter, Doppler shift (frequency increases as the satellite moves towards or decreases as it moves away from the receiver), or shift caused by other phenomena, like clouds or obstacles. The MAPSAT2 receiver overcomes these problems because it incorporates an AFC to track the incoming signal and tune to its peak. Should the signal move due to one of the above effects, or disappear, then the receiver begins to search for it. If the signal is lost for a moment the AFC tries to lock to the nearest signal. The search is slow enough to recapture signals after interruptions of a normal duration have occurred. Interruptions longer than the normal duration will send the receiver searching for a new signal. Another innovative feature of the receiver is a 20-memory storage bank, which can be used for keeping all your favourite satellite frequencies. A start and stop frequency can be programmed into two special memory locations to allow searches over specific regions of the band only, if required. When a number of memories have been programmed, it is possible to scan the band for the desired programmed frequencies. This allows rapid location of satellites when they become available. A neat feature is the ability to look at the frequency stored in a memory prior to retrieving it. This means that you can easily check memory contents, or cue up another frequency ready for use, then by hitting the CALL button it is possible to immediately change frequency. The firmware and controls are easy to use, and are simple enough that you will be able to use the unit almost immediately; yet sophisticated enough to provide all the features you might need.

So regardless of whether you have used MAPSAT original, or are a newcomer to the hobby, tracking the weather and forecasting it for yourself can be an exciting pastime! MAPSAT2 follows in the footsteps of its popular predecessor, and considering the advancements in design and user friendliness, this system is likely to open the way ahead for a new generation in Weather Satellite data reception.

The VHF Satellite Aerial, used for receiving NOAA and METEOR pictures. Simple construction techniques together with highly effective reception, make this aerial ideal when used with the MAPSAT2 receiver.

Common Questions and Answers about Receiving Weather Satellite Images

Below are some of the most frequently asked questions about satellite imaging and its associated techniques.

Q. Do I need a licence?

A. No, the Weather Satellite organisations transmit images in a common format, known as WEFAX, for use by educational and amateur organisations, totally free of charge. That includes us.

Q. Do I need a computer to predict the satellite passes?

A. No. There are some excellent computer programs which may be used to accurately predict a satellite pass, but in this instance it is not essential. The satellites orbit about once every 90-100 minutes, travelling almost directly over the North and South Poles. Due to the earth's rotation, we only 'see' the satellite 2 or 3 times, usually twice a day and always at about the same time, a.m. or p.m. The simplest way to track a satellite is to listen until you hear it as it comes up over the horizon and then start 'recording'. The software lets you pick out the part of the pass you want to see later.

Q. I have heard that EUMETSAT (the EUropean METeorological SATellite organisation) is going to encrypt all of the images soon, does this mean that I won't be able to receive the images?

A. EUMETSAT have stated that they have no intention of encrypting the WEFAX transmissions.

Q. I built the original MAPSAT receiver. Can I use the new interface and software with it?

A. Yes, the interface will work with any make of weather satellite receiver with an audio signal output, but you will need a higher audio output than the original MAPSAT receiver provides. One of the small amp kits from Maplin will bridge the gap, contact Maplin Customer Technical Services Tel: (01702) 556001 for details.

Q. I have heard that the original MAPSAT receiver suffers from out-of-band interference from paging transmitters. Does the MAPSAT2 also suffer?

A. Not an easy answer here! The new receiver is technically much better than the original and does not suffer from the same blocking and cross-modulation problems, but there are two points to consider here:

1. A very strong local signal can overload a receiver.
2. Paging systems in the UK now extend to within the satellite band; although there are no satellites transmitting on the same frequency, users living in close proximity to a paging transmitter may suffer a degradation of the signals on a weak pass.

Q. I want to receive the Meteosat Geostationary satellite images. Can the MAPSAT2 receiver, interface and software do this?

A. Yes, with a suitable down-converter and aerial. As I write this article, the new design is already under way for the down-converter Mk.2 from the Maplin R & D Lab! Watch *Electronics* for its launch, soon.

Further Information

The following organisations can provide information, regular bulletins and satellite tracking software for weather and other satellites.

Remote Imaging Group:

Ray Godden,
Membership Secretary,
RIG-SUB,
PO Box 142,
Rickmansworth,
Hertfordshire, WD3 4RQ.

(RIG is a group dedicated to all weather satellite enthusiasts.)

AMSAT UK:

Mr Ron Broadbent,
AMSAT (UK),
94 Herongate Road,
Wanstead Park,
London, E12 5EQ.

Please enclose a 9 × 6in. (or larger) S.A.E. with a 38p stamp.

(AMSAT UK is the UK `branch' of the international Amateur Radio Satellite organisation.)

TRAKSAT 2.8 (Shareware program):

Paul E. Traufler,
111 Emerald Drive,
Harvest. AL. 35749, USA.
Tel +1 (205) 726-5511 (Work)
+1 (205) 830-8450 (Home)

Further Reading

An introduction to Amateur Communications Satellites, by Alan Pickard (WT24B).
This book gives an introduction to the subject of Amateur Satellite Communications, and covers reception of weather satellite data.

MapSat 2 Receiver	**Order As AQ49D**	**Price £399.99** D7
MapSat 2 PC Interface	**Order As AQ50E**	**Price £99.99** B2
VHF Crossed Dipole Aerial Kit	**Order As LM00A**	**Price £16.99** B2
An Introduction to Amateur Communications Satellites	**Order As WT24B**	**Price £3.95** *NV*

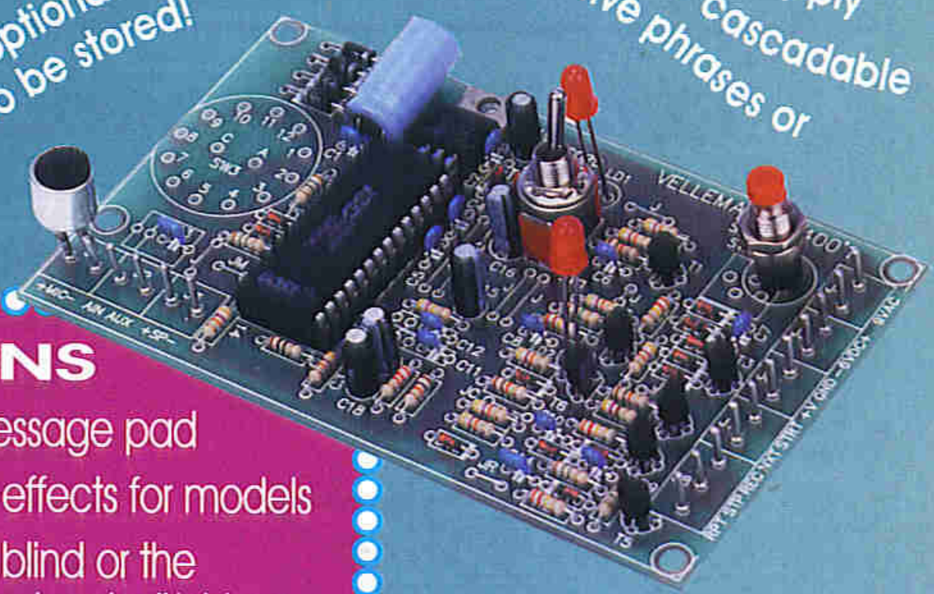
Please note that the receiver and interface are only available in ready built form.

2
PROJECT RATING

The message is clear... This is the ELECTRONIC RECORD/PLAYBACK MODULE it uses non-volatile EEPROM Technology, precisely!

KIT AVAILABLE (VF43W) Price £29.99

★ Excellent recording quality ★ Ten year voice retention ★ Single supply ★ Loudspeaker output ★ Non-volatile memory ★ Modules are cascadable ★ Fitting an optional rotary switch allows up to five phrases or sounds to be stored!



APPLICATIONS

★ Answering machine ★ Message pad
★ Speech for toys ★ Sound effects for models
★ Voice annunciator for the blind or the partially sighted ★ Novelty door bell/chime

Text by Nigel Skeels and Robin Hall

Ker-clonk…whine…whizz-bang! Remember those old endless tape message systems, and everytime that it got to the end of the tape you would hear something resembling the sound of a man being hit with a wet fish, that is of course if you were lucky enough to hear the message. Each time the message was played it would wear a little more of the ferromagnetic material away, thus causing the sound to be eventually completely unintelligible.

The next progression in electronic message recording was the digital recording technique, this involved the conversion of sound from Analogue-to-Digital and the resulting digital code stored in memory. Playback would be the opposite reading the digital information out of the memory and converting it back to analogue sound. As this method does not use mechanical parts, it does not wear in the same way as the previous designs. The draw back with this system is that to store the sound at a reasonable quality, a high sample rate is needed, and obviously with this high sample rate a large amount of memory will be written to very quickly, which can be expensive if lengthy samples are required.

A third method is demonstrated here, in the ISD1016A (part of the ISD1000A family). This method uses ***non-volatile*** EEPROM technology, and allows analogue data to be written directly into the cells without A-to-D or D-to-A conversion. It means lower chip count, and the storage density is eight times greater than conventional digital memory. Another point is that if just a single cell fails in conventional digital EEPROM memory, this renders the whole memory IC unusable. In the ISD1016A, a single cell failure during programming, will only result in an imperceptible change in distortion, and in fact, many hundreds of random failures would have to occur before recording quality noticeably degrades.

Circuit Description

The full block diagram of the Electronic Record/Playback module is shown in Figure 1, with the circuit diagram shown in Figure 2a.

The heart of the circuit is IC1, which is an ISD1016A single chip voice record and playback device. A non-volatile analogue array consisting of 128K cells, which has the equivalent of 1MB of digital storage. The device eliminates the need for complex digital conversion, compression or voice synthesis techniques, which often compromise voice quality and are more complicated to use. Signal conditioning circuits and control functions are included as well as a noise cancelling microphone preamplifier with AGC that can record both high and low volume sounds.

The electret condenser microphone (Mic) is AC coupled via C11 to pin 17 of IC1, with the correct DC bias conditions set up by resistors R4 and R5. The microphone signal is amplified within IC1 by a gain controlled transconductance amplifier, and output is on pin 21. Link JM on the board is required for the signal to pass back to the IC via the external capacitor C13, this is enabled on single boards, and disabled if the microphone and link are not required, such as when boards are used in cascade, or when an external preamplifier is used.

An internal fifth order anti-aliasing and smoothing filter is multiplexed into each circuit function as needed for record and playback, this ensures all digital artifacts are removed. The device is able to drive an 8Ω speaker directly through differential outputs which doubles the voltage drive compared with single-ended operation, and eliminates the need for a series coupling capacitor and separate output amplifier.

Digital address lines A5 to A7 form the method of accessing up to five separate blocks of memory, thus allowing five phrases or sounds to be stored and played back individually, this function is set up with a rotary switch SW3 (not supplied).

Power to the board is from either 6V DC via D13 or 9 to 16V AC which is full-wave rectified via D15 to D18 which form a bridge rectifier. With high and low frequency decoupling supplied by C1 and C20 respectively, and on the output side of regulator VR1 by C2 and C19, the output after D14 is +5·4V DC. Diode D13 provides protection against reversed polarity.

The +5·4V DC supply is fed to pin 16 (VCCA) for the analogue memory sections of the ISD1016 chip, with associated decoupling capacitors C3 and C17, and to pin 28 (VCC) the digital clock and addressing side with associated decoupling capacitors C4 and C16. This helps to keep any digital clock noise out of the signal path thus giving a clear signal.

The remaining circuitry is for control purposes such as repeat, stop, next start, record and start, here we can see links JR, JC and JE; as already mentioned, these links are for cascading modules and so are used to disable or enable repeating and stopping.

A digital end of message marker (EOM) is inserted at the end of each recorded message and is output from pin 25. This is passed via D5 to T6; thus LD2 illuminates when the memory has been totally filled. The EOM signal also is passed via C8 and R21 which integrate the signal to T7, in turn passing a signal pulse to T3.

The supply to T3 and T2 is only enabled when the link JE is made.

Another feature of the project is that it can be made to repeat in playback mode, this is done by connecting the 'RPT' pin to the 'STRT' pin.

Specification

Supply:	9 to 12V AC or 6V DC (only 15μA in standby)
Dimensions:	125 × 70 × 25mm
Recording Time:	16 seconds per module

Splitting the Memory

The memory normally lasts up to 16 seconds, but it is possible to split this up into 5 segments. A 2-pole 6-way rotary switch (FF74R – not supplied) can be fitted to the SW3 position, and modifying it for 5-way operation (see Figure 2b). This then provides the facility of selecting five different recording blocks, which could be useful for storing five different sounds or messages. When fitted, smaller messages can be recorded in the five areas. Care must be taken, as the message will spill over to the next segment if the recording exceeds the allotted time span. LED2, illuminates when the available memory has been used.

The signal outputs from the board may be terminated to either an 8Ω loud speaker or line output. It is important to remember that effectively the output from the IC is matched for 16Ω; a 10Ω pad resistor has been included on the PCB in order for an 8Ω loud speaker to be directly connected.

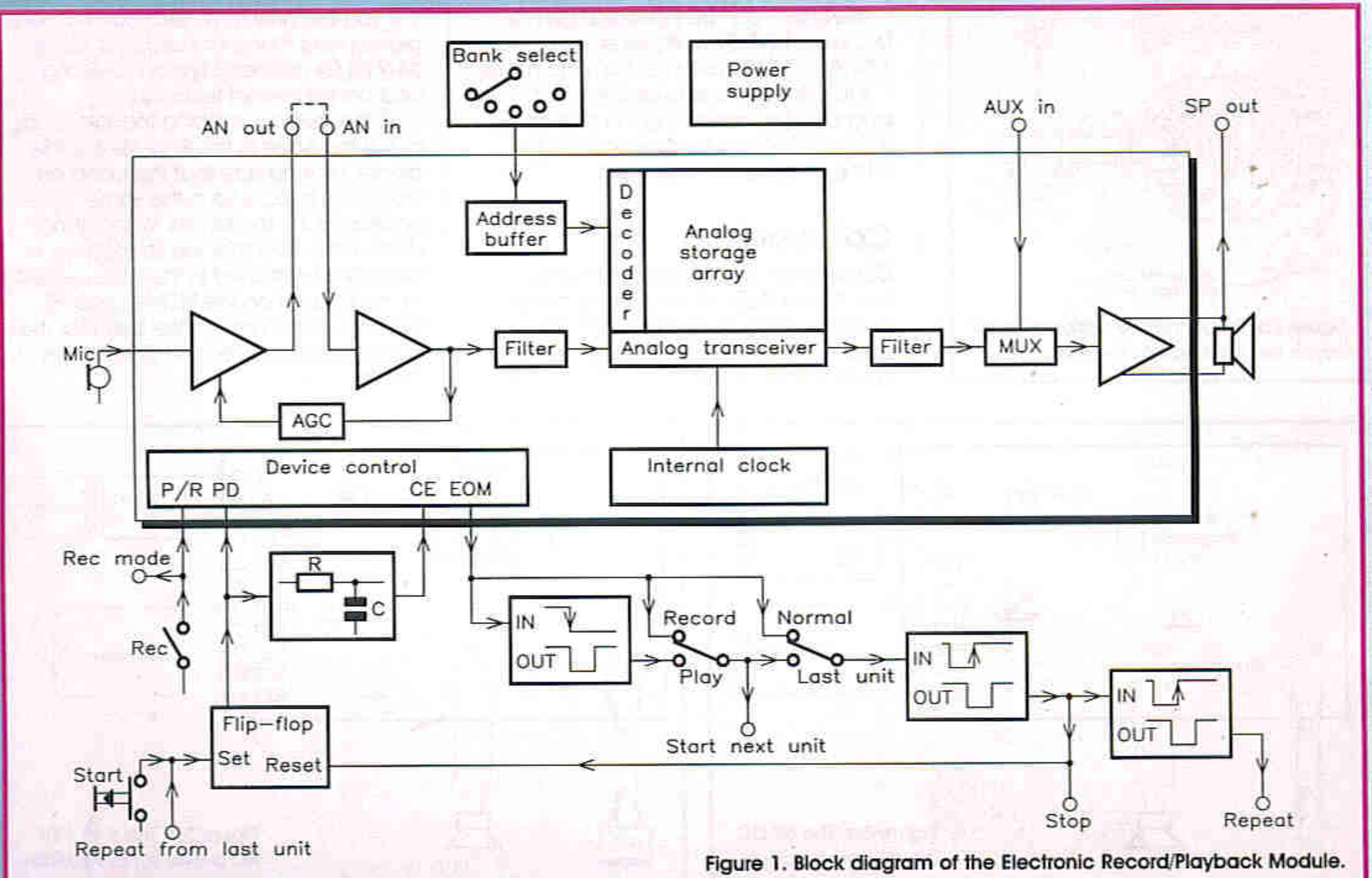


Figure 1. Block diagram of the Electronic Record/Playback Module.

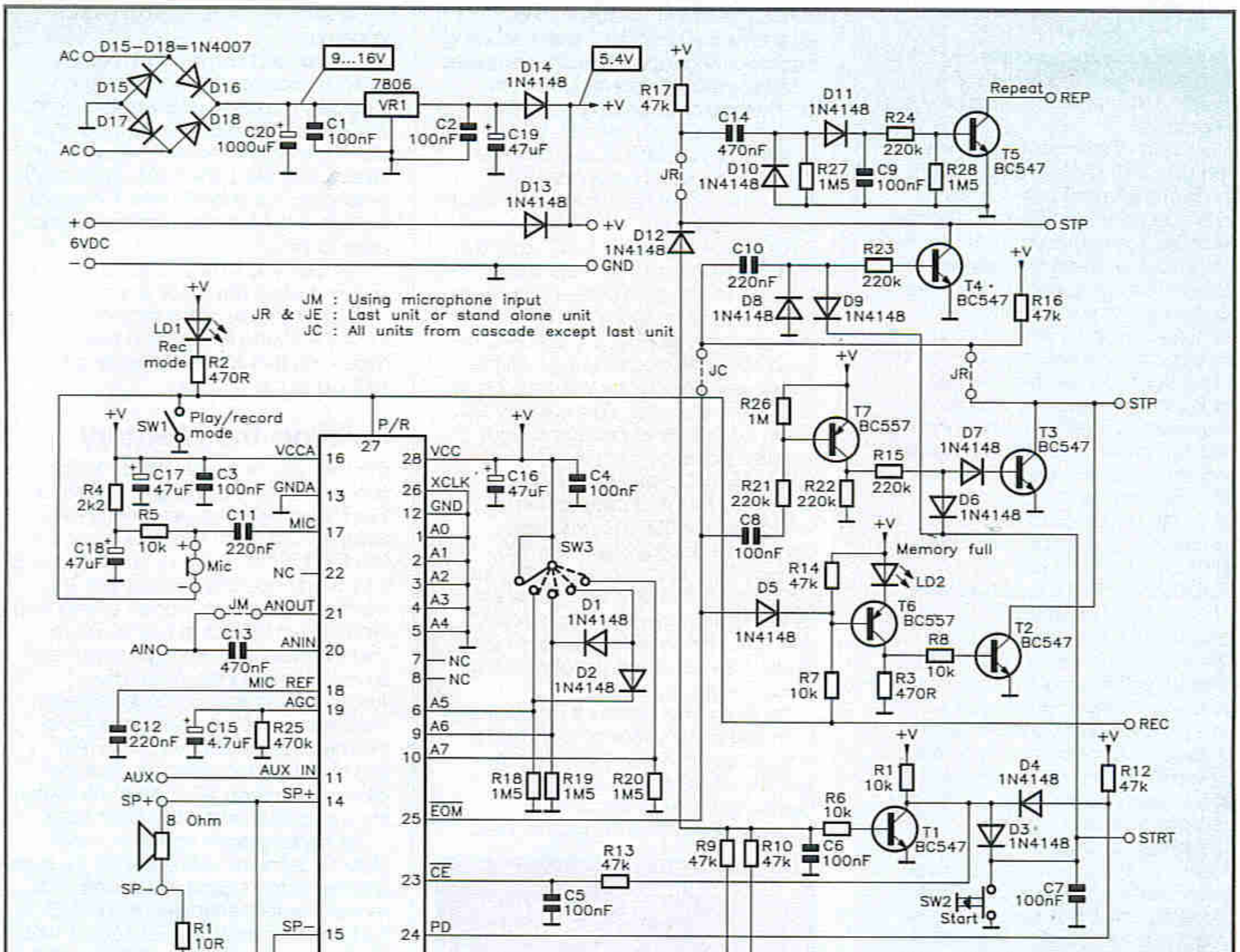


Figure 2a. Circuit diagram of the Electronic Record/Playback Module.

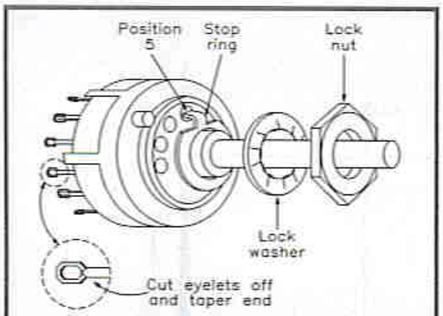


Figure 2b. Preparing the optional rotary switch for insertion into the PCB.

The board can be powered from 6V DC, e.g., 4 3 1·5V batteries or via a 9 to 12V (AC) 0·1A transformer from the mains.

If the storage time available is not long enough, cascading the boards is possible, so that as one recording finishes playing, the next starts.

Construction

Construction is fairly straightforward, refer to the Parts List and to the circuit diagram in Figure 2. Begin with the smallest components first, working up in size to the largest.

If you are new to project construction, please refer to the Constructors' Guide (XH79L) for hints and tips on soldering and constructional techniques.

Fit the resistors, shaping the wire leads to suit the holes in the PCB. Next fit the diodes making sure that the band on the diode is located in the same position as on the board. When fitting LEDs, make sure that the shortest leg of the LED is positioned in the hole nearest to the flat part on the PCB legend. Fit the capacitors next, make sure that the electrolytics are fitted the correct way round.

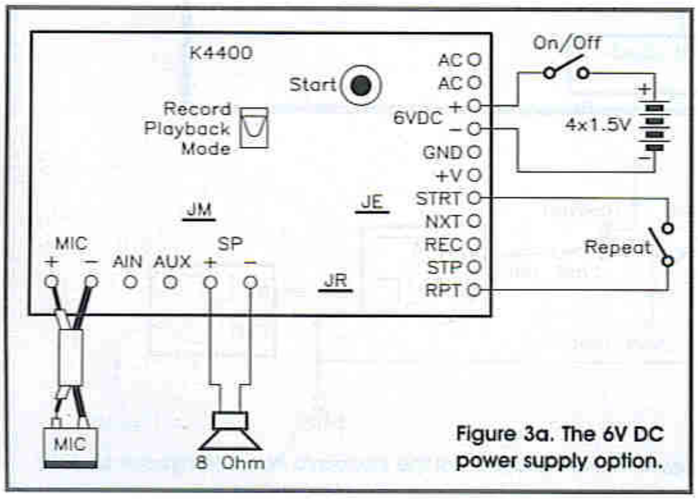


Figure 3a. The 6V DC power supply option.

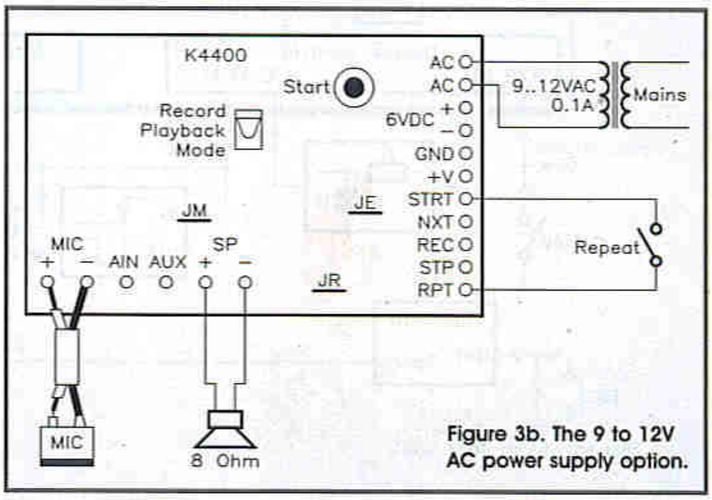


Figure 3b. The 9 to 12V AC power supply option.

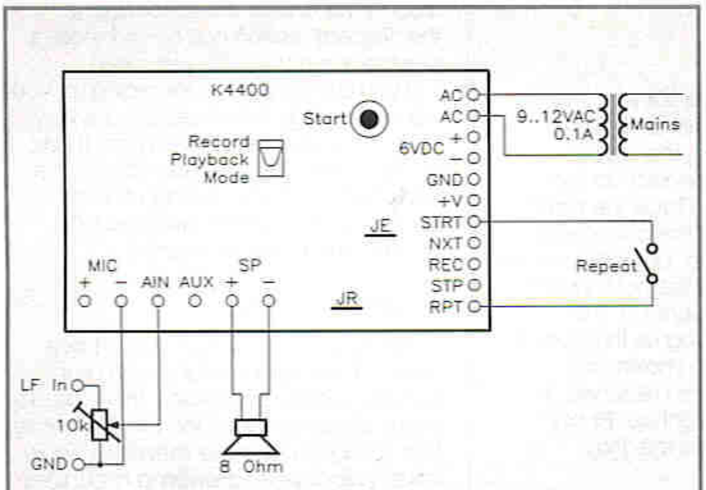


Figure 4. Line level input.

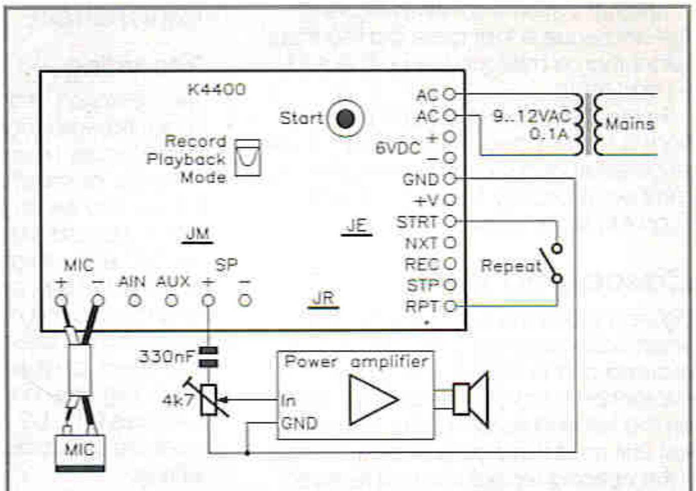


Figure 5. External power amplifier.

Identify the two types of transistor and fit onto the PCB, matching the legend. Preform the legs of the voltage regulator and fit onto the PCB.

Insert the PCB pins into the relevant holes.

Use component wire offcuts for the links marked 'J' on the PCB, and if only one module is being used, fit links JR and JE, refer to Figure 3a. Next identify the two switches, fit the single pole double throw toggle switch to position SW1 marked 'Record Playback Mode', and the push-to-make switch to position SW2, within the circle marked 'Start'.

Next fit the 28-pin DIL IC socket, making sure that the orientation mark on the PCB matches the notch on the socket. Before soldering the socket make sure that it is level on the PCB as once it is soldered in position it will be almost impossible to remove without damage. Fit the IC, making sure that the notch matches the legend and the socket.

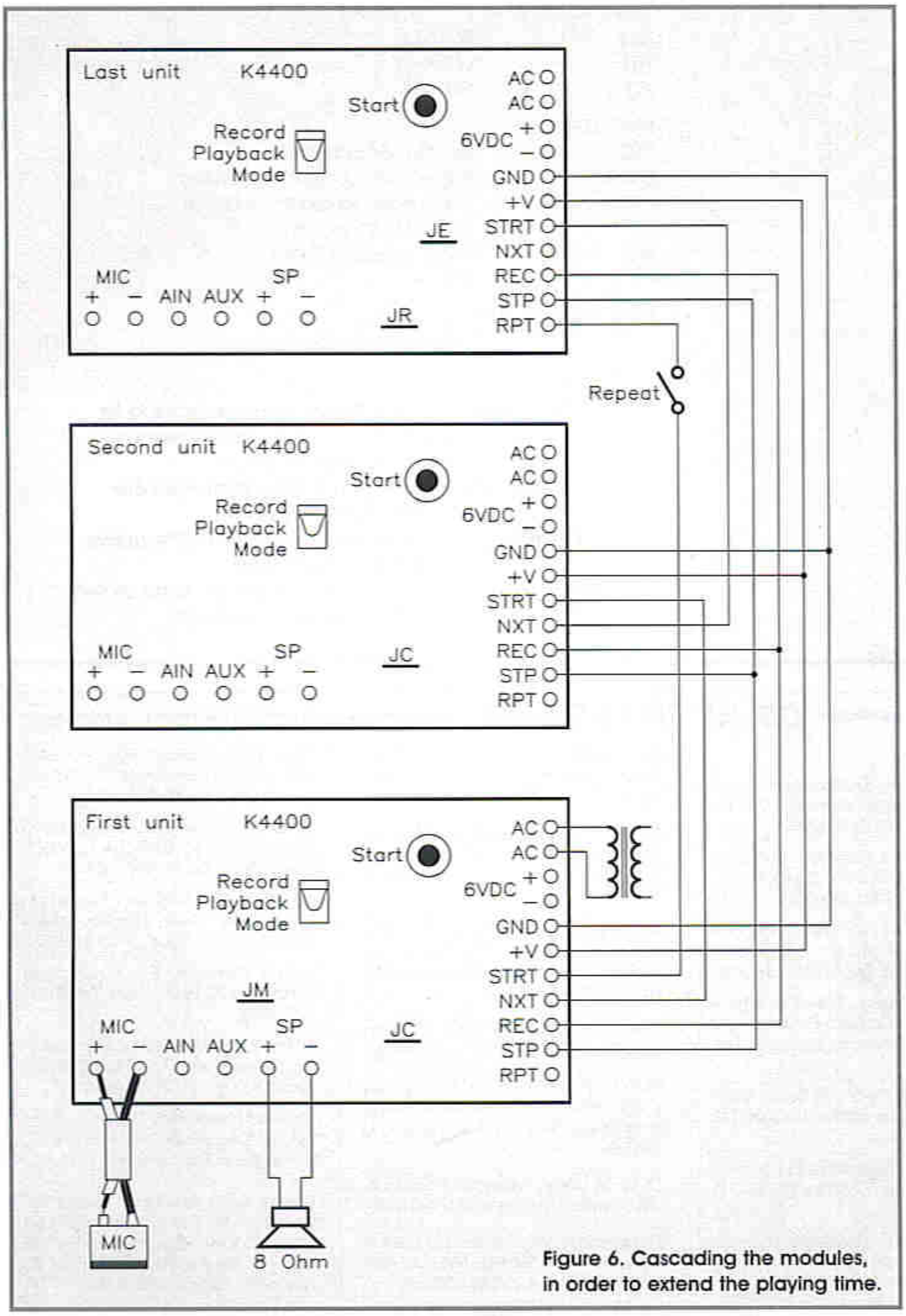


Figure 6. Cascading the modules, in order to extend the playing time.

Options

If it is required to split the available memory into sections, then an optional rotary switch is required. In order for the switch to be mounted onto the PCB, the loops on the rotary switch need to be cut off as shown in Figure 2b. The retaining washer with locating spigot will also have to be correctly repositioned, as this modifies the switch positions, in this case five are required instead of the normal six or twelve.

Ensure that when mounting the switch that the connections on the switch are matched with those on the PCB before soldering in position.

Wiring Options

If the electret microphone is to be used, fit the link JM, and connect the microphone insert across +MIC− as shown in Figure 3a, noting that the earth side of the microphone is connected to the (−). The microphone can be placed a short distance from the PCB using a small length of screened cable if necessary. An 8Ω speaker is connected to SP.

If the 'Repeat' facility is required then a switch should be wired between 'RPT' and 'STRT' on the board.

The supply for this board option is from 4×1·5V batteries via an on/off switch.

Further Options

Rather than running the board off batteries, a mains version is shown in Figure 3b, with the 9 to 12V AC secondary connected to positions 'AC' on the board. The microphone and loudspeaker are connected as before.

Another option is shown in Figure 4, the difference is that there is a line input rather than a microphone connected to (–) and (AIN).

Figure 5 shows a single unit powered from a mains power supply, and the use of an external audio power amplifier. This may be necessary to boost the audio output in some situations.

Cascading the Boards

Figure 6 shows the connections and links when cascading the units. Link JM is only required on the first board with the microphone. Link JC needs to be fitted on the first and second units, and the last unit must have both JR and JE fitted. If the optional repeat switch is required, then this must be fitted between 'STRT' on the first unit, and to 'RPT' on the third.

Note, that if more than five modules are used in cascade with a transformer supply, then the voltage regulator of the first module must be fitted with a heatsink.

Operation

Recording

The operation of the circuit is straightforward, connect an external loudspeaker, or an external power amplifier as shown, connect up the supply and switch on. Place the switch to the 'Record' setting (switch closed), the LED LD1 will light up. Decide on what you want to say, press the push switch and talk into the microphone. The recording will last as long as the button is pressed, or when the maximum recording time has been reached, in this case LED LD2 will light up. Finally reset the switch back to the 'Play' setting.

Playback

Make sure that the switch is in the 'Play' position, both LEDs should be extinguished. Press the push switch, but do not keep it pressed down. The message will start and automatically stop at the end of the recording. If the 'Repeat' option has been installed, playback is continually repeated.

If you do not like the recording, or you wish to change the message, it is very easy to repeat the above steps. There is a ten year memory retention on the ISD1016A, so the recording will not vanish with the system switched off or when the board is inactive.

Applications

These days, voice annunciators have become more common, such as in cars lifts, clocks and radios. There are so many applications for this project, some that spring to mind are message pads, novelty door bells, answering machines for the phone or the door, toys, sound effects for models, voice indicators for the blind or partially sighted.

This might give you an idea as to where this project can be used, and in some cases fitted at a fraction of the cost of the commercial equivalent. E

ELECTRONIC RECORD/PLAYBACK MODULE PARTS LIST

RESISTORS: All 0·25W 5% Metal Film			
R1	10Ω	1	
R2,3	470Ω	2	
R4	2k2	1	
R5-8	10k	4	
R9-17	47k	9	
R18-20	1M5	3	
R21-24	220k	4	
R25	470k	1	
R26	1M	1	
R27,28	1M5	2	
CAPACITORS			
C1-C9	100nF Monolithic Ceramic	9	
C10-12	220nF Monolithic Ceramic	3	
C13,14	470nF Monolithic Ceramic	2	
C15	4μ7F 50V Radial Electrolytic	1	
C16-19	47μF 16V Radial Electrolytic	4	
C20	1000μF 25V Radial Electrolytic	1	
SEMICONDUCTORS			
D1-14	1N4148	14	
D15-18	1N4007	4	
LD1,2	Red LED 5mm	2	
T1-5	BC547B	5	
T6,7	BC557B	2	
VR1	L7806CV	1	
IC1	ISD1016	1	
MISCELLANEOUS			
MIC	Electret Microphone	1	
SW1	Single-pole Push-to-make-switch	1	
SW2	Single-pole Double-throw Switch	1	
	28-pin DIL IC Socket	1	
Pins	Single-ended PCB Pins	17	
	PCB	1	
OPTIONAL (Not in Kit)			
	2-Pole 6-Way Rotary Switch	1	(FF74R)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available in kit form only.

Order As VF43W (Electronic Record/Playback Module) Price £29.99

Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

DIARY DATES

Every possible effort has been made to ensure that the information presented here is correct prior to publication. To avoid disappointment due to late changes or amendments please contact event organisations to confirm details.

1 to 4 December. Christmas Computer Shopper Show, Grand Hall, Olympia, London. Tel: (0181) 742 2828.

6 December. Open Forum – Questions & Answers on 'Anything Related to Amateur Radio', Sudbury and District Radio Amateurs. Tel: (01787) 313212.

6 to 7 December. DSP – Digital Signal Processing Exhibition, Ramada Heathrow, London. Tel: (0181) 547 3955.

6 to 8 December. International Online/CD-ROM Exhibition, Olympia, London. Tel: (01865) 730275.

12 to 14 December. Digital Signal Processing for Communication Systems, University of Warwick, Warwick. Tel: (01254) 65201 Ext 5822.

1995

17 to 19 January. Outdoor Event & Live Music Production, Wembley Centre, London. Tel: (01203) 694393.

29 January to 1 February. European Lightshow Exhibition, Earls Court, London. Tel (01952) 290905.

7 to 9 February. ISDN USER – Integrated Communications Exhibition, Olympia, London. Tel: (01733) 394304.

14 to 16 February. SMARTCARD – International Smart Card Exhibition and Conference, Olympia, London. Tel: (01733) 394304.

1 to 2 March. Electronic Books International, Wembley Centre, London. Tel: (0171) 976 0405.

7 to 9 March. Computers in Libraries, Wembley Centre, London. Tel: (0171) 976 0405.

16 to 19 March. Computer Shopper Show, NEC, Birmingham. Tel: (0181) 742 2828.

9 to 11 April. European Computer Trade Show, Business Design Centre, London. Tel: (0181) 742 2828.

22 April. Special International Marconi Day exhibition station at Puckpool Park Wireless Museum, IOW. Tel: (01983) 567665.

8 May. Working wartime CW shortwave station to celebrate VE-Day at the Puckpool Park Wireless Museum, IOW. Tel: (01983) 567665.

16 to 18 May. Internet World, Wembley Centre, London. Tel: (0171) 976 0405.

14 to 15 June. Government Computing & Information Management, Royal Horticultural Halls, London. Tel: (0171) 587 1551.

27 to 29 June. Networks Exhibition, NEC, Birmingham. Tel: (0181) 742 2828.

2 September. Wight Wireless Ralley at the Arreton Manor Wireless Museum, near Newport, IOW. Tel: (01983) 567665.

10 to 13 September. PLASA – Light and Sound Trade Show, Earls Court, London. Tel: (0171) 244 6433.

19 to 21 September. Computers in Manufacturing Exhibition, NEC, Birmingham. Tel: (01932) 564455.

20 to 21 September. Electrical Engineering Show, Hinckley Island Hotel, Hinckley. Tel: (01732) 359990.

4 to 6 October. Electronic Data Exhibition, ICC, Birmingham. Tel: (0181) 742 2828.

12 to 13 October. Electrical Engineering Show, Forte Post House Hotel, Basildon. Tel: (01732) 359990.

10 to 12 November. Design & Technology Education Exhibition, NEC, Birmingham. Tel: (01425) 272711.

Please send details of events for inclusion in 'Diary Dates' to: The News Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

CLASSIFIED

Placing an advertisement in this section of *Electronics* is your chance to tell the readers of Britain's Best Selling Electronics Magazine what you want to buy or sell. or tell them about your club's activities–Absolutely Free of Charge! We will publish as many advertisements as we have space for. To give a fair share of the limited space, we will print 30 words free, and thereafter the charge is 10p per word.

Placing an advertisement is easy! Simply write your advertisement clearly in capital letters, on a post-card or sealed-down envelope. Then send it, with any necessary payment, to: Classifieds *Electronics–The Maplin Magazine*. P.O. Box 3, Rayleigh, Essex SS6 8LR. Advertisements will be published as soon as possible, space allowing. No responsibility is accepted for delayed publication or non-inclusion of advertisements.

Readers who have reasonable grounds to believe they have been misled as to the nature of an advertisement are advised to contact the Publisher and their local Trading Standards Office.

AUDIO

TASCAM 644 MULTI-TRACK RECORDER, complete £730. Bantam 96-way 1U patchway, unused £150. DENON PRA1500 remote control preamplifier, as new £160. ADCOM 60+60W stereo slave amplifier, £200. Tel: Neil (01953) 883533.

DYNAUDIO DRIVERS, top quality 4 × 17W75 Woofers, 2 × ESOTEC Tweeters, £30 each. Free cabinets and networks if bought together. Also 2 × 17W75XL. Tel: (0181) 902 0189 for details.

COMPUTERS

COMMODORE 64 MIDI UTILITIES; filter, real-time/storage analyser, channeliser, data filer. £17. For detailed information, send S.A.E. to: D. Williams, 12 Old Forge Way, Skirlaugh, N. Humberside, HU11 5DX.

VARIOUS

TWO 49-NOTE KEYBOARDS, 13-note pedal board and swell pedal from dismantled MES 53 organ. Offers. Tel: (0925) 762782.

MINIATURE 12V FILAMENT BULBS, (4mm diameter) with 250mm leads attached. 15p each or 10 for £1. Send cheque/P.O. to: M. Knight, 10 Daniel Road, Mancetter, Atherstone, Warks., CV9 1PA.

TOPWARD 7021 SCOPE. 20MHz. Plus probe kit and service manual. £120 o.n.o. Tel: (0181) 688 2484. (Croydon, South London).

GIANT CLEAROUT! Deceased engineers collection of new capacitors, resistors, test gear and meters, available for sale. No reasonable offer refused. Tel: Duncan (01259) 720676. (Grangemouth area).

OSCILLOSCOPE, advance 40MHz dual trace, dual timebase. Excellent condition with complete manuals. £250. Tel: (01443) 207037.

WANTED

COMPUTER – Radio Shack TRS 80 Model III instruction manual and circuit diagram. Tel: (01637) 874168.

OSCILLOSCOPE, 20MHz, must have probes and instruction manual. (No old valve models please). Tel: (01493) 369269. (Norfolk area).

2 CHANNEL OSCILLOSCOPE. Must be in good working condition. Tel: (01788) 528 353.

OPERATING INSTRUCTIONS and/or circuit diagram for Electrosonic E50 combined cassette recorder/slide projector changer, (probably a pulse change unit). Contact: J. Graham, 27 Murrayshall Road, Scone, Perth, PH2 6QP.

ANY SAGE AUDIO EQUIPMENT. Especially SUPERMOSS 200 (working or not). Tel: Tony Bricknell (01702) 554155 Ext. 244 (work) or (01702) 231427 (home).

WINDSOR MODEL 45B VALVE TESTERS service/operational manual. Tel: Alan Williamson (01702) 554155 Ext. 247 during (office hours).

INFORMATION OR KNOWLEDGE on Sugden 'Connoisseur' disc cutting lathe. Also, books and articles on disc cutting required. Contact: Mr. Bird, 54 Wesley Road, London, E10 GJF or Tel: (0181) 556 0770.

PCB BOARD, (Maplin order code GE03D) wanted urgently. This is the board that goes with the s/w receiver circuit in *Electronics* Issue No. 29 (Vol. 8). Contact: John Noble, 1 Miers Court Farm Cottages, Miers Court Road, Rainham, Kent, ME8 8PJ. Tel: (01634) 233058.

BAIRD FLATPLATE NEON TUBE, Galaxy III/V, wartime *Radio Times*, R1082/T1083. Tel: (01983) 567665. (Isle of Wight).

BBS CORNER

APPLE CRACKERS. FirstClass Client BBS, mainly for AppleMac and PC users. Baud rate 2·4K-bit/s to 14·4K-bit/s, 8 data bits, no parity, 1 stop bit. Tel: (01268) 781318/780724.

MACTEL METRO/ICONEX. FirstClass Client BBS, AppleMac and PC users. E-mail address on Internet for registered users. Baud rate 2·4K-bit/s to 14·4K-bit/s, 8 data bits, no parity, 1 stop bit. Tel: (0181) 543 8017 (Metro) or (01602) 455444 (Iconex).

CLUB CORNER

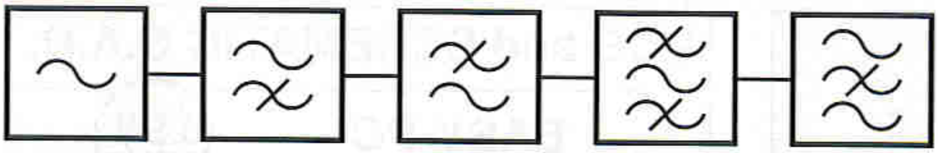
CRYSTAL PALACE & DISTRICT RADIO CLUB. Meets on the third Saturday of each month at All Saints Church Parish Rooms, Beulah Hill, London SE19. Details from Wilf Taylor, (G3DSC). Tel: (0181) 699 5732.

MODEL RAILWAY ENTHUSIAST? How about joining 'MERG', the Model Electronic Railway Group. For more details contact: Mr. Eric Turner, Treasurer MERG, 38 North Drive, Orpington, Kent BR6 9PQ.

THE LINCOLN SHORT WAVE CLUB meets every Wednesday night at the City Engineers' Club, Waterside South, Lincoln at 8pm. All welcome. Further details from Pam, (G4STO) (Secretary) Tel: (01427) 788356.

SOUTHEND & DISTRICT RADIO SOCIETY meets at the Rocheway Centre, Rochford, Essex every Friday at 8pm. For further details, contact: F. Jensen, (G1HQQ) P.O. Box 88, Rayleigh, Essex SS6 8NZ.

WIRRAL AMATEUR RADIO SOCIETY meets at the Ivy Farm, Arrowe Park Road, Birkenhead every Tuesday evening, and formally on the the 1st and 3rd Wednesday of every month. Details: A. Seed (G3FOO), 31 Withert Avenue, Bebington, Wirral L63 5NE.



FILTERS

Part 4: Band-pass and Notch Filters, Including Tuned Circuits

J. M. Woodgate B.Sc.(Eng.), C.Eng., M.I.E.E., M.A.E.S., F.Inst.S.C.E.

In this series, Part 1 dealt with low-pass filters, on which also can be based the design of high-pass filters, covered in Part 2, and band-pass or band-stop filters, covered in Part 3. Before moving on to notch filters, there is one type of band-pass filter that could not be covered in Part 3, but which is attractive for simple, and even some more critical, projects. This Part also deals with tuned circuits, which can be used as notch filters and as band-pass filters.

Multiple-Feedback Active Band-Pass (MFBP) Filter

The circuit of Figure 35 can be shown to produce a band-pass frequency response. The maximum band-pass Q is limited by the open-loop gain A_{ol} of the op amp:

$$Q_{max} << \sqrt{\frac{A_{ol}}{2}}$$

so that the very high open-loop gain of the TLE2027 (CP86T), at 153dB or 44·7 million, will provide a maximum band-pass Q of about 500 if we take '<<' to mean 'less than one ninth of'. The more common op amps with open-loop gains of around 100dB (100 thousand) provide maximum Q values of about 20.

The design equations for the component values are:

$$R_2 = \frac{2Q_b}{\omega_0 C}$$

$$R_1 = \frac{R_2}{2A_c}$$

$$R_3 = \frac{R_2}{4Q^2 - 2A_c}$$

where:

ω_0 is 2π times the centre-frequency of the band-pass response,

Q_b is the band-pass Q, the ratio of the centre-frequency to the –3dB bandwidth,

A_c is the required gain of the filter at its centre-frequency.

The value of the two equal capacitors C can be chosen to obtain convenient values of resistors. Clearly, the centre-frequency gain of the filter cannot exceed $2Q^2$, until Maplin stock negative resistors for use in the R_3 position! This circuit has the advantage that its characteristics can be adjusted quite easily:

- the centre-frequency gain can be set by adjusting R_1
- the Q can be set by adjusting R_2

Since both of these operations may affect the centre-frequency, the final operation is:

- the centre-frequency can be set by adjusting R_3.

Figure 35. Multiple feedback band-pass filter section.
Figure 36. ⅓-octave band-pass filter for 1kHz.

A Practical Example

Band-pass filters with a bandwidth of ⅓ octave are very often used in audio measurements and electroacoustics. The response shapes of these filters are standardised in IEC225 and BS2475. For this example, we will design a filter with a centre-frequency f_o of 1kHz.

First we determine the bandwidth in Hertz. The pass-band on each side of the centre frequency is ⅙ octave, which is a frequency ratio of $\sqrt[6]{2}$ = 1·12246. So the –3dB frequencies are 1122·46Hz and 1000/1·12246 = 890·90Hz. The overall bandwidth is thus 231·6Hz. We should select a Butterworth filter, because we want a flat top to the band-pass response, with no 'rabbit's ears'. The standard specification requires the stopband response to be below –13dB at 800Hz and 1250Hz, so using the formula given in Part 3, the order n of the filter is given by:

$$n \geq \frac{0{\cdot}05a}{\log A_s}$$

where a is the required stopband attenuation and A_s is the shape factor, the ratio of the bandwidth at attenuation a to the bandwidth at –3dB. The result is that n must exceed 2·25, but clearly it must be a whole number, so we choose n = 3. This means that we shall need three 'sections' like Figure 35.

The next step requires that we know the positions of the poles of the filter in the complex plane. In general, this is a tedious mathematical problem, but for Butterworth filters it requires only a little complex number theory, to wit, de Moivre's Theorem. The positions of the poles of an n-th order Butterworth low-pass filter are the n-th roots of –1, which are given by the formula:

$$\left(\frac{\cos r\pi}{n}, \frac{j\sin r\pi}{n}\right)$$

where r takes integer values from 0 to $n-1$. In this case, n = 3, so the poles are at

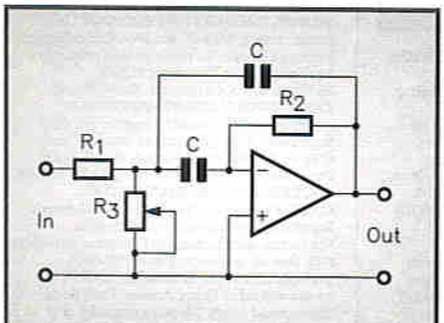


Figure 35.

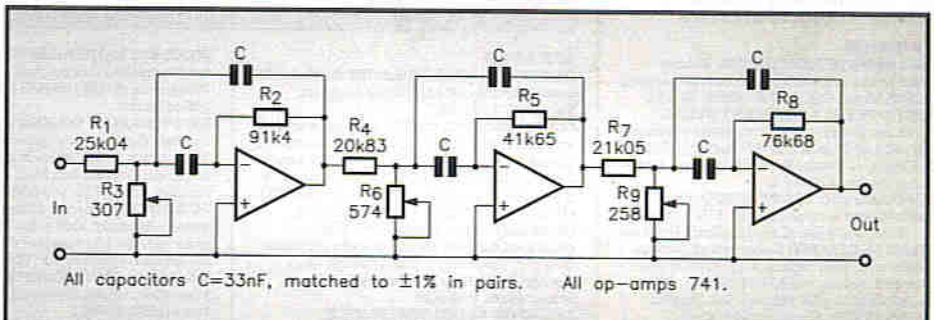


Figure 36.

(–1, 0) and $(-1/2 \pm j\sqrt{3}/2)$. The other value we need is the band-pass Q, Q_b, which is 1000/231·6 = 4·318.

The two complex poles (the ones with j in) result in two filter sections with the same Q, but different centre-frequencies. The real pole at (–1, 0) results in a single filter section with a different Q, centred at the centre-frequency of the whole filter. To calculate the filter sections realising the complex poles, we follow a procedure using 'intermediate variables' so as to avoid very complex equations. Intermediate variables are just assigned letter symbols for the calculation and do not necessarily have any particular physical significance.

To find the section Q, Q_s, we define the complex pole positions as $(-\alpha, \pm j\beta)$, and we found above that $\alpha = 1/2$ and $\beta = \sqrt{3}/2$. We go on to evaluate the intermediate variables:

$C = \alpha^2 + \beta^2 = 1$ for any Butterworth filter.

$$D = \frac{2\alpha}{Q_b} = \frac{1}{Q_b} = 0{\cdot}2316$$

$$E = \frac{C}{Q^2} + 4 = 4{\cdot}0536$$

$$G = \sqrt{E^2 - 4D^2} = 4{\cdot}0270$$

and, at last!

$$Q_s = \sqrt{\frac{E+G}{2D^2}} = 8{\cdot}6790$$

To find the centre-frequencies f_{s1}, f_{s2}:

$$M = \frac{\alpha Q_s}{Q_b} = 1{\cdot}0039$$

$$W = M + \sqrt{(M^2 - 1)} = 1{\cdot}0918$$

$$f_{s1} = f_o W = 1091{\cdot}8\text{Hz}$$

$$f_{s2} = \frac{f_o}{W} = 915{\cdot}9\text{Hz}$$

To find the characteristics of the section to realise the real pole, for which $\alpha = 1$:

$$Q_s = \frac{Q_b}{\alpha} = 4{\cdot}318$$

$$f_s = f_o = 1000\text{Hz}$$

We need three sections in cascade, and an overall gain of 1. We can simply set the gain of the real-pole section to 1. The gains A_c of the complex-pole sections are higher at their centre-frequencies than the gains A_o at the centre-frequency of the whole filter. The equation is:

$$A_c = A_o \sqrt{1 + Q_s^2\left(\frac{f_o}{f_s} - \frac{f_s}{f_o}\right)^2}$$

and we want $A_o = 1$. This gives $A_c = 1{\cdot}825$ (5·23dB) for each section (the values differ in the fourth decimal place, and, for another filter specification, could be much more different).

We now have all the information necessary to design the whole filter, and the resulting circuit values are shown in Figure 36. Since the value of the capacitors can be chosen to give convenient resistor values, 33nF was chosen in this case. This is particularly attractive, because a full set of ⅓-octave filters covers the frequency range from 20Hz to 20kHz, with extensions down to 2Hz and up to 160kHz if you can afford them. We can change the centre-frequency simply by changing the capacitor value, and we find that 20Hz requires 1·65µF and 20kHz requires 1·65nF, which are quite practical. Indeed the value of 16·5µF for 2Hz is reasonable, but 206pF for the 160kHz filter is rather small for reliable design. For such a frequency, however, wide-band op amps would also be essential. The odd resistor values can be made up from two 1% tolerance preferred-value components in series or parallel.

It is worth noting that the exact values of the capacitors are not so critical, as long as they are matched in pairs. For example, a pair of capacitors that measure 34·5nF can be used if all the resistor values for that section are divided by 34·5/33. With 741 op amps, a practical circuit showed slightly low Q and section gain values, although the overall response was within the standard specification limits. Figure 37 shows the theoretical and practical results. Each section of the filter is tuned up with its preset resistor to its correct centre-frequency, using an X-Y oscilloscope display to set the phase-shift from input to output to zero. The gain and –3dB bandwidth can then be measured and tweaked if necessary, before connecting the sections in cascade and checking the overall gain and response shape. The practical results shown in Figure 37 were obtained without this final tweaking.

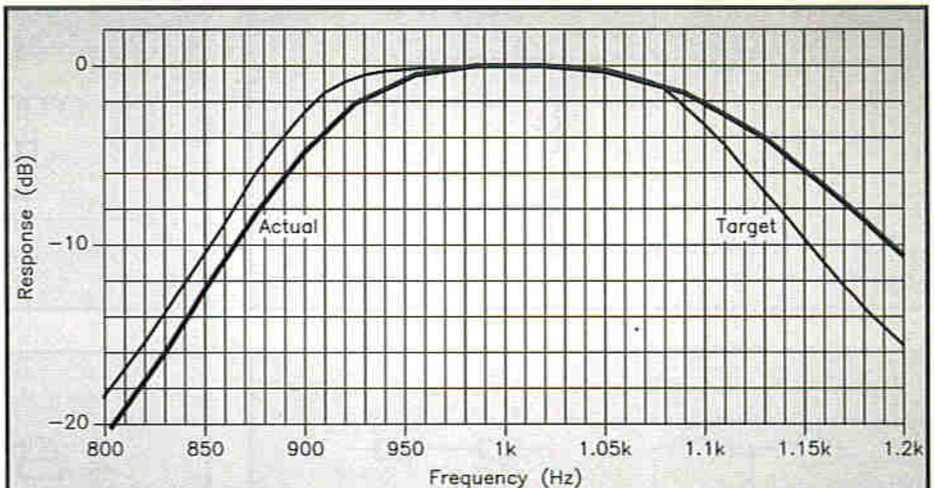


Figure 37.

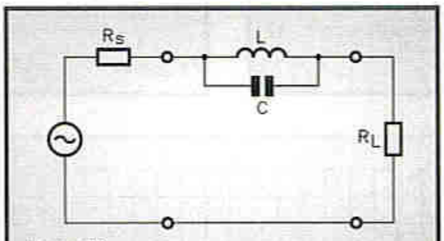


Figure 38.

Figure 37. Target response (thin) curve of the ⅓-octave band-pass filter and the actual response (thick) measured before final tweaking. Figure 38. Parallel-tuned notch filter or trap.

Notch Filters

Notch filters, or null networks or traps, are usually used in order to remove a specific frequency from a signal (such as the fundamental in a distortion detector), without bothering too much about the precise attenuation that other frequencies suffer. They can be less complex than band-stop filters (see Part 3), but have limitations in consequence. The most obvious is wide bandwidth at –3dB, which means that other signals may be undesirably attenuated.

The Parallel-Tuned Trap

The basic circuit for this is shown in Figure 38. Since the impedance of a parallel-tuned circuit is high at resonance, this trap works best between low source and load impedances. The attenuation at the resonant frequency depends on the Q of the resonant circuit, which usually means the Q of the inductor, since the capacitor Q is much higher.

The notch frequency f_o is given by the usual resonant-circuit equation:

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

while the –3dB bandwidth f_3 is given by:

$$f_3 = \frac{1}{2\pi(R_s + R_L)C}$$

I have put these equations in the order they are usually found in textbooks, *but your design starts with the second one!* If you start with the first one, you can't choose C to get the bandwidth right. The attenuation A_x in decibels at any frequency f_x is given by:

$$A_x = 10\log\frac{1 + f_3^2}{(f_o - f_x)^2}$$

The attenuation A_o at the notch frequency is given by:

$$A_o = 20\log\left(\frac{Q_L}{Q_b} + 1\right)$$

where Q_L is the Q of the inductor (surprise!) and Q_b is the band-reject Q, f_o/f_3. For example, a filter to reject 4·5kHz, with a –3dB bandwidth of 500Hz and $Q_L = 100$, has a notch 'depth' of just under 22dB. Reducing the bandwidth to 250Hz *reduces* the notch depth to 16·3dB for the same Q_L.

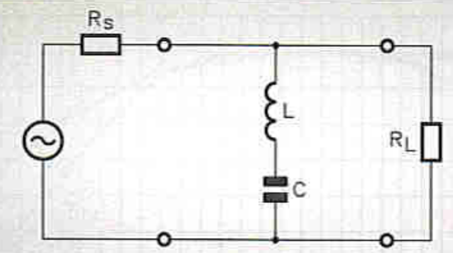


Figure 39.

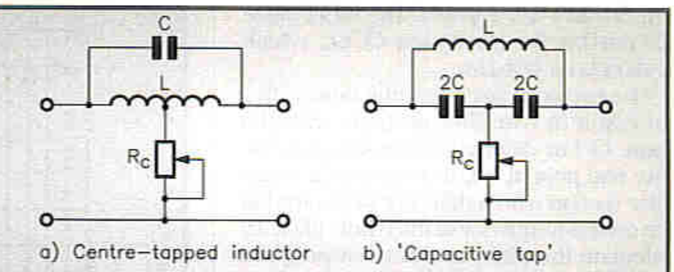


Figure 40.

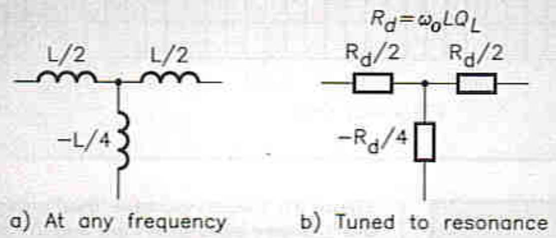


Figure 41.

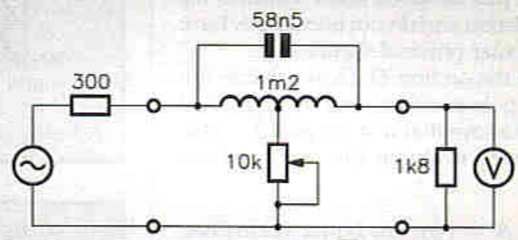


Figure 42.

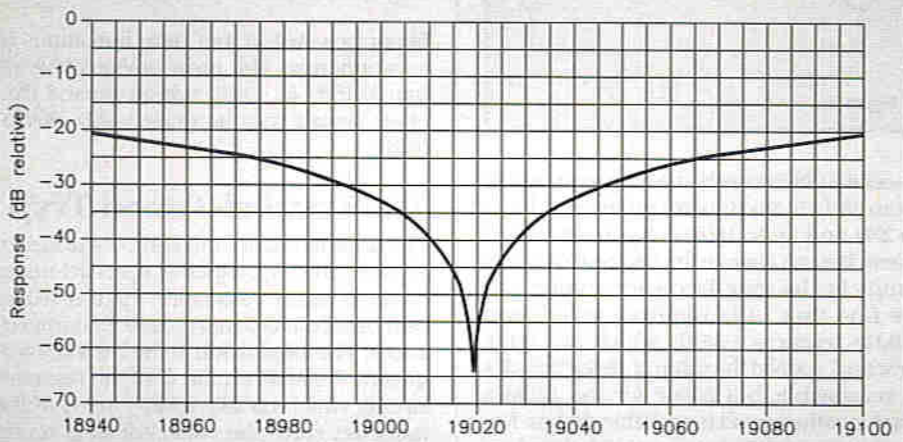


Figure 43.

The Series-Tuned Trap

You may well not be surprised to find that this trap works best between high source and load impedances. Figure 39 shows the basic circuit, and using the same symbols as for the parallel-tuned trap, we find:

$$f_3 = \frac{R_s R_L}{2\pi L(R_s + R_L)}$$

and

$$C = \frac{1}{4\pi^2 f_o^2 L}$$

The response shape and the Q_L requirement for a given notch depth are the same as for the parallel trap.

The Bridged-T Circuit

This is a very interesting and useful circuit, because it can theoretically give infinite attenuation at the notch frequency, and it does this by synthesising a negative resistance in a passive circuit. The two versions are shown in Figure 40: the centre-tapped inductor is convenient if you can wind your own, while the 'capacitive tap' version uses a standard inductor but requires two matched capacitors for the best performance. The resistor R_c is often made a preset, to maximise the notch depth. If very high attenuation is required, it is essential

Figure 39. Series-tuned notch filter or trap.
Figure 40. Bridged-T notch filters; a, centre-tapped inductor; b, 'capacitive trap'.
Figure 41. Equivalent circuits of a centre-tapped inductor; a, at any frequency; b, tuned to resonance.
Figure 42. Practical bridged-T circuit set up for measurements.
Figure 43. Close-in response curve of the 19kHz bridged-T filter shown in Figure 42.

to use high-quality components and to take into account, for example, temperature coefficients, not only of the main value of the component but, for example, of the capacitor losses (Q or $\tan\delta$).

It is easier to see how the negative resistance arises if we look at the tapped inductor. If the inductance measured between the end is L, that measured from one end to the centre tap is $L/4$, since the inductance is proportional to the square of the number of turns. If we resonate this inductor at angular frequency ω_o with a parallel capacitor, the impedance of the whole tuned circuit is a resistance equal to $\omega_o L Q_L$ at resonance. However, from one end to the centre tap there appears a resistance of only one quarter of this, which can only be explained if the equivalent circuit of the tapped inductor includes a negative inductance, which tunes to give a negative resistance as shown in Figure 41. The T-junction points in these equivalent circuits are physically unreachable, but the negative resistance can be cancelled out by means of an ordinary resistor in series with the centre tap, so that a signal at the notch frequency is completely short-circuited. This technique is called 'resistance compensation'.

Another Practical Example

I happen to have a high Q 1·2mH inductor, bifilar wound so that it is accurately centre-tapped. This resonates with 58·5nF at 19kHz, so making a trap for the 19kHz pilot tone used in FM stereo radio. Figure 42 shows the test circuit, where the source and load resistances just happen to be convenient values for the oscillator and voltmeter used for the measurements. Figure 43 shows the frequency response in just the immediate vicinity of the notch, and you can see how sharp it is. Although over 60dB attenuation was obtained at the exact tuning frequency of 19019Hz, the attenuation at 19000Hz was only a little over 30dB. In fact, it was possible to get 75dB attenuation by very careful adjustment of the preset resistor, but even breathing on the circuit changed the value considerably! Without the compensating resistor, that is, just using the circuit as a parallel tuned trap, the notch depth was only 10·6dB.

This circuit can be very practicable even for volume production. It was used for the 3·5MHz sound trap in Ferguson and Kolster-Brandes 405-line television sets, for example, with a preset inductor for tuning and a fixed (5% tolerance, in the days when that was special!) compensating resistor.

The name of this circuit and the concept of adjusting something for a precise null may remind you of bridge circuits. In fact, it is possible to show that the bridged-T is equivalent to a bridge circuit, but with the advantage that there is a common terminal for input and output, so that a balanced source or load is not required.

The Parallel-T Circuit

This is another circuit equivalent to a bridge, but it uses only resistors and capacitors. It must be driven from a low impedance source and requires a high impedance load. The circuit is shown in Figure 44, and for predictable results the components must be well matched. It is normal practice to match up four resistors and four capacitors and to use two components in parallel in each shunt arm. The component values are related to the notch frequency by:

$$f_o = \frac{1}{2\pi RC}$$

To tune the notch frequency, it is necessary to vary all three components of the same type, which is usually very inconvenient. The band-pass Q has the very low value of $\frac{1}{4}$, so that the –3dB bandwidth is $4f_o$. We can find the –3dB frequencies f_1 and f_2 as follows. The response is symmetrical on a logarithmic frequency scale so that:

$$f_1 f_2 = f_o^2$$

and we know that:

$$f_2 = f_1 + 4f_o$$

so, substituting for f_2 in the first equation:

$$f_1^2 + 4f_1 f_o - f_o^2 = 0$$

which leads to:

$$f_1 = (-2 \pm \sqrt{5})f_o$$

The two roots, in fact, are the values of f_1 and f_2, and are $0{\cdot}236f_o$ and $4{\cdot}236f_o$. (If you solve the equations for f_2 instead, you get one value as $-0{\cdot}236f_o$. We met negative frequencies in Part 1: the negative sign can be ignored in almost all cases without causing any problem.) This means that a filter with a notch at 1kHz has 3dB attenuation at 236Hz and 4236Hz, which is a very soggy notch indeed.

It is possible to sharpen up the notch by using the parallel-T in a positive feedback configuration with an op amp, and this technique is used in distortion meters. However, the problem of having three variable components to tune the beast remains. Besides, to get a negligibly low attenuation at the second harmonic frequency (to measure the distortion accurately), the circuit requires not only much positive feedback but also careful component layout to minimise stray capacitance, especially from input to output.

Tuned Circuits

We have already looked at tuned circuits as notch filters, but they are mostly used as band-pass filters, and almost always in the parallel configuration.

Figure 45 shows a single-tuned circuit in a band-pass filter configuration. The source and load impedances must be much higher than the resonant impedance of the tuned circuit, otherwise one or both damp the circuit and thus widen the bandwidth.

Figure 44. Parallel-T notch filter.
Figure 45. Parallel-tuned circuit a band-pass filter with matched source and load impedances.
Figure 46. Equivalent circuit of the parallel-tuned band-pass filter at resonance.
Figure 47. Insertion loss and *Q* ratio as functions of the resonant to load impedance ratio.

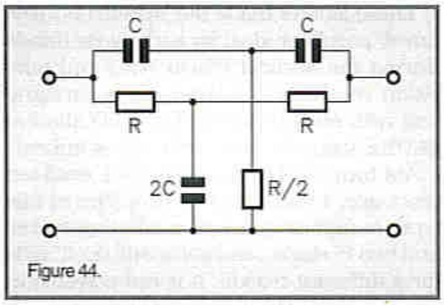


Figure 44.

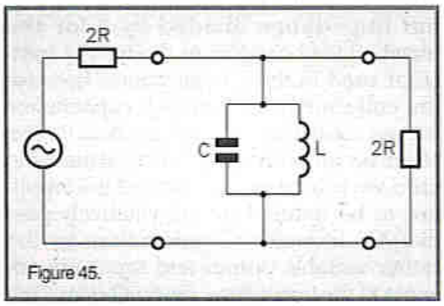


Figure 45.

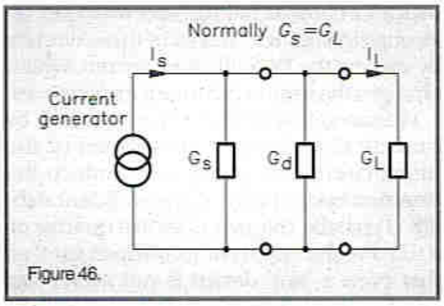


Figure 46.

This means that even at the peak in the frequency response, the filter has significant insertion loss. It is possible to allow for some loading effect in the design process. We must not blame the tuned circuit for all the losses. There is a basic insertion loss due to the source and load impedances, which is a minimum of 6dB when the impedances are equal (Maximum Power Theorem). In this analysis, we assume that the source and load impedances are purely resistive, because any reactive components are 'tuned out' when the tuned circuit is adjusted to the correct resonant frequency.

The design equations are:

$$C = \frac{1}{2\pi R f_c}$$

and

$$L = \frac{1}{4\pi^2 f_o^2 C}$$

where R is the total parallel resistance in the circuit of Figure 45, that is, the parallel combination of R_s, R_L and the resonant impedance of the tuned circuit, which is $2\pi f_o L Q_L$. f_c is the required –3dB bandwidth, f_o is the centre-frequency of the pass band and Q_L is the Q of the inductor. At the centre (resonance) frequency, the equivalent circuit is as shown in Figure 46, from which we can determine the insertion loss. Because all the components are in parallel, this is a case where the calculation is easier if we work with a current generator and conductances rather than a voltage generator and resistances. Referring to the quantities marked on the circuit diagram, Figure 46, we find, for the normal case where the source and load are matched (that is, $G_s = G_L$):

$$\text{Power in } G_L = \frac{I_L^2}{G_L} = \left(\frac{I_s G_L}{G_s + G_L + G_d}\right)^2 \times \frac{1}{G_L}$$

$$= \frac{I_s^2 G_L}{(2G_L + G_d)^2}$$

since $G_s = G_L$. In the absence of the tuned circuit, the power in G_L would be $I_s^2/4G_L$, so the insertion loss IL is the ratio of these:

$$IL = \frac{4G_L^2}{(2G_L + G_d)^2}$$

By substituting resistance values for the reciprocals of conductances, that is, $R_L = 1/G_L$ and $R_d = 1/G_d$, we can get the insertion loss in more familiar terms:

$$IL = \frac{4R_d^2}{4R_d^2 + 4R_L R_d + R_L^2}$$

and, since this is a *power* loss, the value in decibels is ten times the logarithm of IL. Figure 47 shows how the insertion loss and the ratio of unloaded to loaded Q vary with the ratio of resonant impedance R_d to the load impedance R_L. Note that this applies only to the case where the source and load are matched for maximum power transfer.

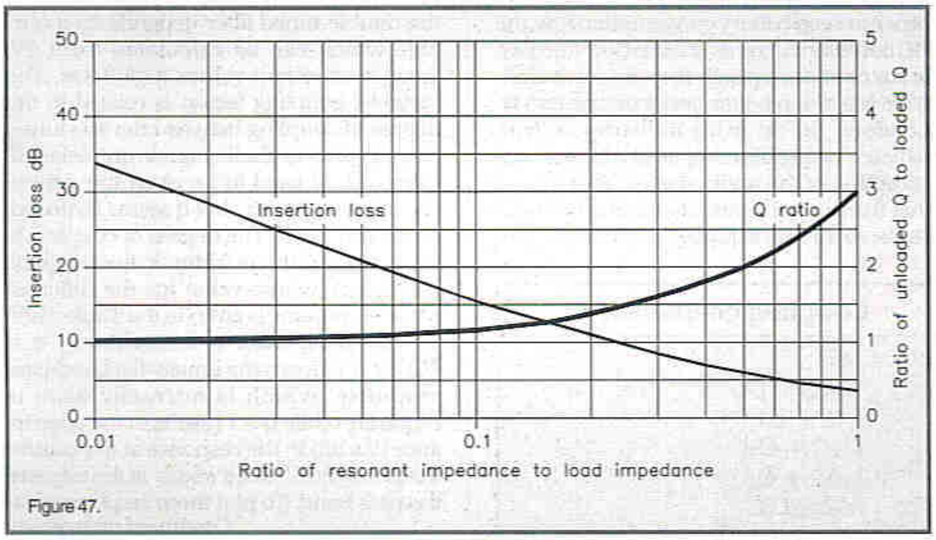


Figure 47.

Cascaded, Isolated Single-Tuned Circuits

If we make a chain of amplifying stages, each including a single-tuned circuit as a band-pass filter, the overall response has some interesting properties:

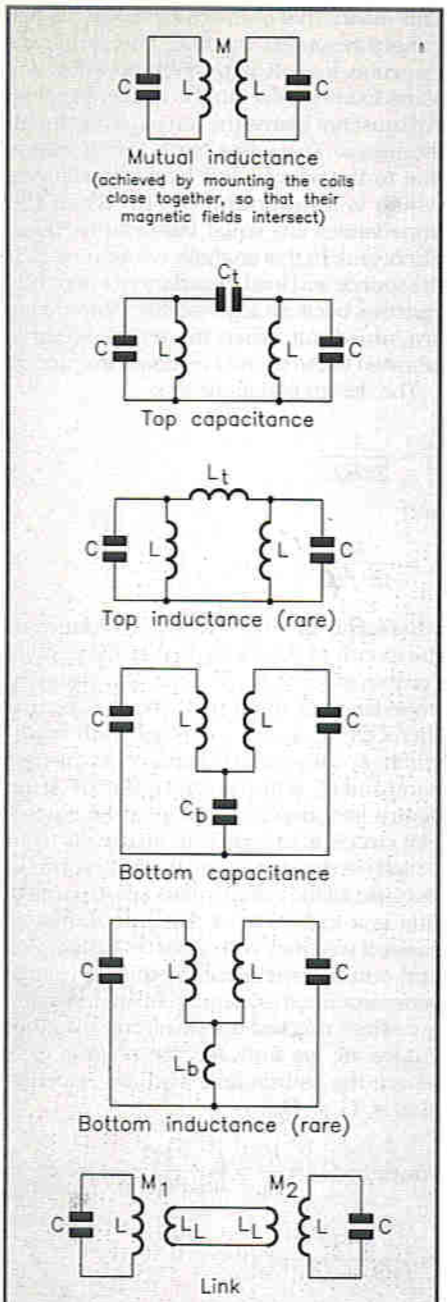


Figure 48.

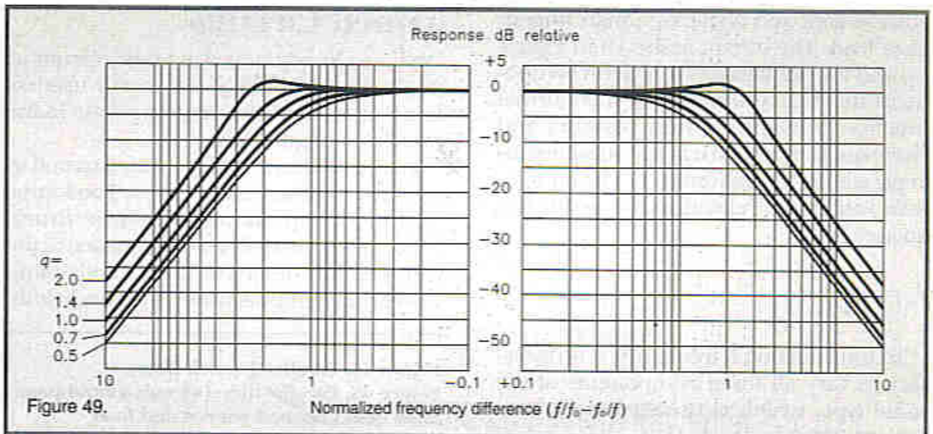


Figure 49.

- For a given overall bandwidth, the individual tuned circuits require a *wider* bandwidth, in contrast to the case of the ⅓-octave filter, which was 'stagger-tuned', and required higher section *Q* values than the overall value.
- It can be shown that the response to pulse waveforms is very good: the response to a step has no overshoot or ringing and the response to an impulse does not ring.
- The design, manufacture, alignment and testing of a number of identical amplifier stages, using the same coils and tuned to the same frequency, is particularly simple.
- However, the overall response shape is very broad at high attenuations. One section gives 20dB attenuation at one tenth of or ten times the centre-frequency, but two stages give only 33dB, while four stages give only 52dB. This is even soggier than for Bessel filters.

These factors made the 'synchronously-tuned' amplifier ideal for early radar (made during the Second World War) and television receivers, the latter being 'straight' sets with several stages of amplification at 45MHz, using EF50 or SP61 valves (tubes).

AM transistor radios also used, until ten years ago, a three stage IF amplifier of this type, comprising a self-oscillating mixer and two IF stages, and some still do. This is for a different reason. It is not possible to obtain the apparent maximum gain (mutual conductance times collector output impedance divided by 2 for the matched load case) from the type of transistor used in these applications, because the collector-base feedback capacitance causes oscillation. The same effect (Miller effect) occurs with triode valves. At the same time, we want the bandwidth of the amplifier to be defined by the relatively predictable inductor *Q* rather than by the rather variable output and input impedances of the transistors, especially since the amplifier requires automatic gain control (AGC) to combat fading, and overload on strong signals. AGC works in these circuits by varying the DC collector current, which changes the input and output impedances.

We can satisfy all these requirements by making the resonant impedance of the tuned circuit low enough to produce the insertion loss required to give sufficient stability. Typically, the gain is set at a quarter or a third of the apparent maximum gain, so that even a 'hot' device is not even near enough to oscillation to produce a distortion of the band-pass response shape. In order to keep battery consumption low, the DC collector currents are kept low (too low, in my opinion: typically they are set at 1mA, whereas much better performance can be obtained for an extra milliamp or two, which is negligible compared with the consumption of the audio stages). This means that the mutual conductance is only about 39ms, so three adequately-stable stages give only just enough gain to make the receiver acceptably sensitive. In order to get sufficient selectivity, the tuned circuits must have unloaded *Q* values, at 468kHz in Britain, of the order of 100, which, with size and cost limitations, means using ferrite pots.

Figure 48. Types of coupling between two tuned circuits.
Figure 49. Response curves of double-tuned coupled circuits, for five values of coupling factor *q*.

Tuned Coupled Circuits

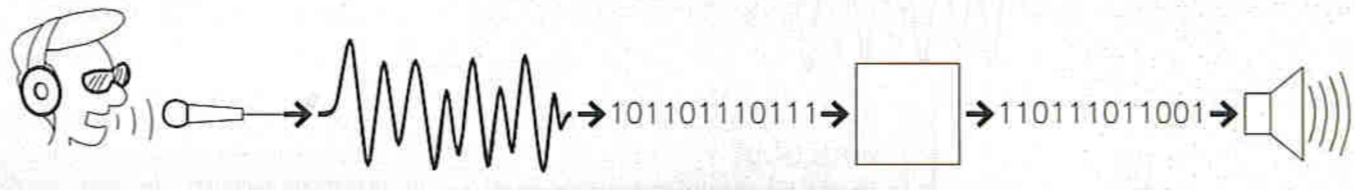
A full treatment of this subject needs a book, and several have been written, many horribly mathematical. The opportunities in this subject for generating huge equations are surpassed only, perhaps, by those offered by the T-equivalent circuit of the bipolar transistor. We shall restrict our studies to double-tuned circuits in which the two circuits have identical inductance, capacitance and *Q* values, and Figure 48 shows the possible ways of coupling them. For most modern coil constructions, mutual inductive coupling is not practicable, but it is the only form which produces a precisely symmetrical band-pass response. However, if the ratio of bandwidth to centre-frequency (the band-pass *Q*) is 10 or more, all types of coupling give only a minimum amount of asymmetry.

For a given 3dB bandwidth, a double-tuned filter has only half the resonant impedance of the corresponding single-tuned filter, which explains why double-tuned filters are now not used in transistor AM radios – remember that IF gain is at best only adequate. The response shape of the double-tuned filter depends on a variable which can be calculated from the basic component values as follows. The variable, coupling factor, is related to the degree of coupling between the two tuned circuits and to their (equal) unloaded *Q* values Q_u. It used to be given the symbol Q_k, but now the symbol q seems favoured, so we will use it. The degree of coupling is expressed by the quantity k, the coupling coefficient, whose value for the different types of coupling is given in the Table, (left). The coupling factor is then given by $q = kQ_u$. $q = 1$ gives a maximally-flat band-pass response, which is normally what is required, while $q > 1$ results in the appearance of a dip in the response at the centre-frequency and 'rabbit's ears' at the edges of the pass band. To plot these responses, we

Continued on page 46.

Coupling type	Coupling coefficient k
Mutual inductance	M/L
Top capacitance	$C_t/(C + C_t)$
Top inductance	$L/(L + L_t)$
Bottom capacitance	$C/(C + C_b)$
Bottom inductance	$L_b/(L + L_b)$
Link	M_1M_2/L_LL

Part Three by Jason Sharpe **AN INTRODUCTION TO**



DIGITAL SIGNAL PROCESSING

This month, we use the DSP Workbench program to examine various filters and their responses.

DSP Workbench (DSPWB)

The basic building blocks, described previously, can be arranged in many ways to produce filtering effects. Figure 14 shows the arrangement used by the DSP Workbench program. DSPWB allows the number of delay units, n, to be varied, n>0. To define your own filter, enter the number of delay units required, and the multipliers p(0) to p(n) and q(1) to q(n). When tested on a 486DX based PC, the response was reasonable, but on a 286 various stages may take several seconds. Decreasing the sequence length (option 2) will speed things up.

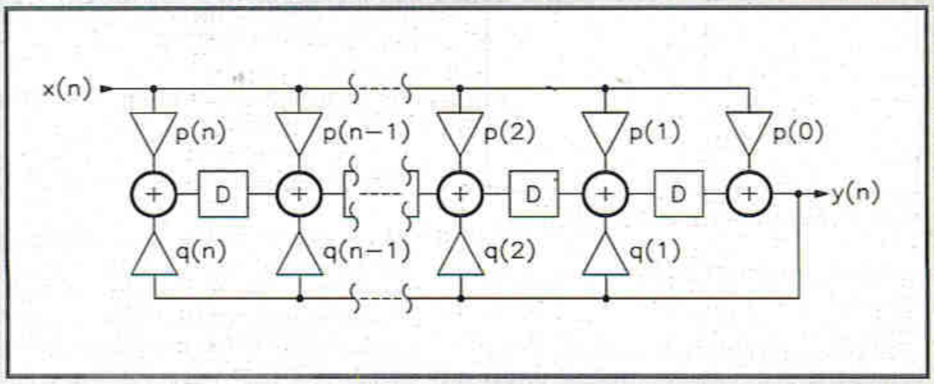


Figure 14. General form of filter used by DSP Workbench program.

Impulse

Run DSPWB, and choose option 1 to define a filter. When asked the order required enter *1*, for one delay unit. For p(0) enter *1*, and for p(1), q(1) enter *0,0*. The result is a 'filter' in which the output is equal to the input, or y[n]=x[n]. This can be written

$$\frac{y[n]}{x[n]} = 1 \text{ or } h[n] = 1 \text{ where } h[n] = \frac{y[n]}{x[n]}$$

h[n] is called the transfer function.

As the filter is just a straight connection, choosing option 3 will display a step, an impulse, the frequency spectrum of an impulse, and a phase shift graph. The phase response shows how the phases of various frequency components are shifted. As this is worked out using inverse tan, the result ranges from +PI/2 (+90°) to −PI/2 radians (−90°). We shall ignore the phase response for the time being.

Apart from the phase graph, the axes are automatically scaled for the best resolution. The vertical divisions are drawn every half and the horizontal at every sample point. If the vertical signal becomes large, or if a long sequence is used, the result will be the same as filling the screen with grey – if you wait that long!

The frequency axis ranges from 0 to $f_s/2$. If the frequency response is plotted above $f_s/2$, it is a mirror image about $f_s/2$, due to the aliasing effect.

Filters

Find the responses of the low-pass filter from part 2. The order should be set to 1 and p(0)=0·5, p(1)=0·5, q(1)=0 (for brevity this will be written (1; 0·5; 0·5, 0) from here on). This filter has a gain of 1; multiplying the p values by 2, giving (1; 1; 1, 0), results in a filter with a gain of 2. Option 4 allows a user defined sequence to be filtered. The default is an exponential sawtooth wave, which can be changed by modifying the data statements, as commented in the listing.

What will happen if p(1) is changed from 1 to −1? The filter response is reversed, producing a high-pass filter. Change the custom sequence to

DATA 0,0,1,1,1,2,2,2, 0,0,1,1,1,2,2,2, 0,0,1,1,1,2,2,2, 0,0,1,1,1,2,2,2

This filter is also sometimes called a differentiator, as it produces a peak for every 'edge'. The peak is equal in size and sign to the change in input, similar to the mathematical differentiation function.

Enter the values (4; 0·0625; 0·25, 0; 0·375, 0; 0·25, 0; 0·0625, 0). This is a fourth-order low-pass filter; notice how the frequency response falls faster than the first-order filter. Entering the values (2; 0·5; 0, 0; −0·5, 0) produces a band-pass filter response. Again, if p(2) is negated, the response is 'reversed', resulting in a band-stop response.

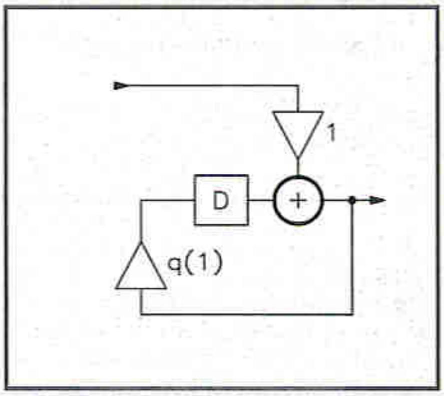


Figure 15. Simple IIR filter.

IIR Filters

The above filters have their q multipliers set to zero, i.e. there is no feedback. They are known as FIR (Finite Impulse Response) filters as the

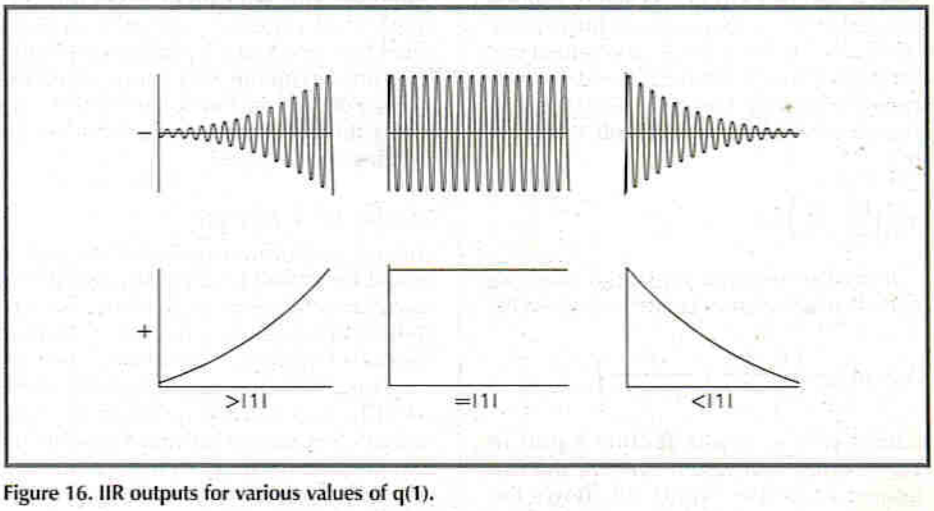
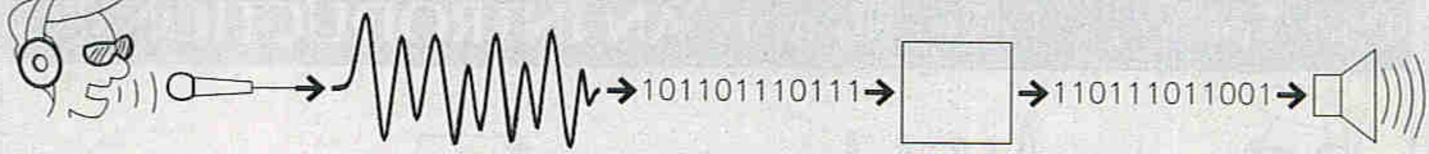


Figure 16. IIR outputs for various values of q(1).



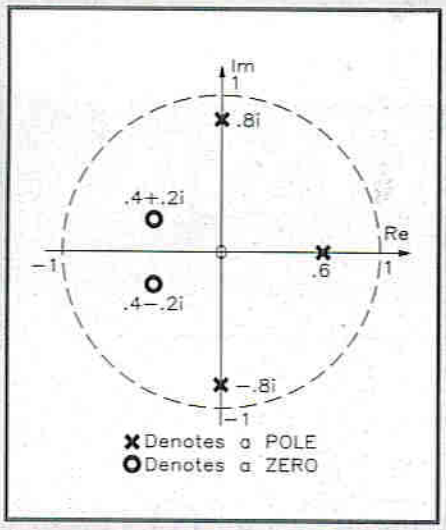


Figure 17. Example of a pole-zero diagram.

impulse response will decay to zero in a finite time, determined by the number of delay units.

IIR (Infinite IR) filters have feedback, so the impulse response can be infinitely long. When experimenting, any values can be used when an FIR filter is being used. Figure 15 shows a first-order recursive filter. Set p(0)=1, p(1)=0, and try various values of q(1) from −1·1 to +1·1. Figure 16 shows the impulse responses for various values of p(1); the value at t=0 is 1 on all of the graphs. If the absolute value is greater than 1 (written $|p(1)|>1$), then the output will increase to infinity, and the system is said to be unstable. When p(1)=−1, we have an $f_S/2$Hz oscillator. With $|p(1)|<1$, the output decays towards zero; the smaller the value the faster the decay. Systems with this response are said to be Bounded Input (produces a) Bounded Output (BIBO) stable, and this is a desirable characteristic. When q(1)=1 we have an integrator; it sums the area under the input waveform, as does the mathematical integration function.

Experiment with various values of order, and p & q. Which values cause unstable filters? Unfortunately, to answer this some mathematics are required.

Z-Domain and Transfer Functions

Transfer functions, mentioned previously, are used to represent filter functions mathematically.

The output of Figure 15, for example, is

$$y[n]=p_0x[n]+q_1y[n-1] \qquad (1)$$

Instead of using the rather copious x[n] notation, z^{-n} will be used as a 'tag' to denote the place in the list, for example:

$x[0]+3x[1]+2x[2]+...+x[n]+...$ becomes $z^0+3z^{-1}+2z^{-2}+...+z^{-n}+...$

or $X(z)=1+3z^{-1}+2z^{-2}+...+z^{-n}+...$ as $z^0=1$.

If $X(z)=1+z^{-1}+...+z^{-n}+...$ is passed through a delay block, the output will be $z^{-1}+...+z^{-n}+...$, which is the same as multiplying the sequence X(z) by z^{-1}. If X(z) is passed through a delay block, the output will be $z^{-1}X(z)$, so (1) becomes

$$Y(z)z^0=p_0X(z)z^0+q_1yz^{-1} \Rightarrow Y(z)=p_0X(z)+q_1Y(Z)z^{-1}$$

which can be rearranged to give the transfer function H(z) (=Y(z)/X(z)):

$$(1-q_1z^{-1})\,Y(z)=p_0X(z) \rightarrow H(z)=\frac{P_0}{(1-q_1z^{-1})}$$

The general filter transfer function is

$$H(z)=\frac{Y(z)}{X(z)}=\frac{p_0z^0+p_1z^{-1}+...+p_mz^{-m}}{1+q_1z^{-1}+...+q_mz^{-m}}=\frac{P(z)}{Q(z)}$$

where P(z) and Q(z) are polynomial equations in z. The values of z for which P(z)=0 are called the 'zeroes', as H(z) is zero at these points. When Q(z)=0, H(z) becomes large, and these points are called 'poles'. The solutions may have a factor of $\sqrt{-1}$. Numbers of this form are called complex numbers.

Not So Complex Numbers

Before continuing, a brief introduction/review of complex numbers is necessary, see the references [1] and [2] for more details.

Complex numbers have the general form a+ib. *a* is the real part, numbers used in everyday life. The imaginary part, *ib*, is a real number multiplied by $\sqrt{-1}$, e.g., 10i, where $i=\sqrt{-1}$. j is sometimes used instead of i to avoid confusion with current. The basic rules and notations are:

$i \times i=-1 \quad i/i=1$

$(a+ib)(c+id)=(ac-db)+i(ad+bc)$

$|a+ib|=\sqrt{a^2+b^2}$ called the modulus

$\arg(a+ib)=\tan^{-1}\left(\frac{b}{a}\right)$ this is the argument

$e^{iz}=\cos z+i\sin z$

$(a+ib)^*=a-ib$ this is called the conjugate

Poles or zeroes with imaginary parts occur in conjugate pairs, i.e. if a+ib is a solution, a−ib is also a solution. It is useful because $(a-ib)(a+ib)=a^2+b^2$, which is real.

Pole-Zero Diagram

The poles and zeroes can be plotted on a diagram with the real components along the x axis, and imaginary along the y axis (see Figure 17). The unit circle is a circle of 1 unit radius, with its centre at (0,0).

We can now return to the stability problem. If any of the poles lie outside the unit circle the system will be unstable; the further from the unit circle, the faster the output will grow.

Next month, we see how the pole-zero diagram can help us design filters. A simple 2D filtering program will also be presented.

References

[1] Bostock L., and Chandler S., *Mathematics – The Core Course for A-Level*, Stanley Thornes, 1987, pp.532-563.

[2] Bajpai, Calus, and Fairley, *Maths for Engineers and Scientists Vol.1*, Wiley & Sons, 1990, pp.479-531.

FILTERS – *Continued from page 44.*

need a special form of variable to express the frequency, and we met one form of half of it in the equation for A_c, the gain of one section of the ⅓-octave filter at its own centre-frequency. This variable, which with stunning originality we will call *x*, is given by:

$$x=\left(\frac{\omega}{\omega_0}-\frac{\omega_0}{\omega}\right)Q_u$$

It can then be shown that the response curve (voltage gain in decibels) is given by:

$$A=10\log\left(\frac{1-\beta x^2}{q^2+1}+\frac{x^4}{(q^2+1)^2}\right)$$

where β is a 'shape factor' equal to $2(q^2-1)/(q^2+1)$, and is zero for the flat-topped response. Figure 49 shows the response obtained with different values of *q*, and readers of Part 3 will perhaps notice that I have cracked the problem of plotting the curves with the log of normalized frequency difference (that funny variable *x*) as x-axis: the graph plotter won't do it but the drafting program will.

Helical Filters

Having mentioned these in passing, it would be as well to close this Part with a few more informative words on the subject. Helical filters employ helical resonators instead of inductors, as they can provide very high *Q* values at frequencies above 100MHz or so. A helical resonator is a cross between a screened coil and a coaxial line, and consists normally of a metal tube or can, with one end open, containing a coil, one end of which is normally connected to the closed end of the can. At some frequency, the free end of the coil and the can 'look like' the terminals of a short-circuited quarter-wave line, and thus present a very high resistive impedance. Below this resonant frequency, the component appears inductive, and can be represented by a series-tuned LC circuit of very high *Q*. Helical resonators can be used in all sorts of filters in the 100MHz to 1·8GHz frequency range, but because of the connection to the can, it is normally necessary for one terminal to be earthed.

Next Time

Next time, I hope to look at more precise active filter circuits, using special 'continuous-time' (i.e. analogue!) ICs.

Stray Signals

by Point Contact

Technology of Yesteryear

Electronics in its widest sense has come a long way in the last century and a half. Not a very profound thought perhaps, but prompted by a visit in the summer to Osborne House, the Isle of Wight get-away-from-it-all retreat of Queen Victoria and Prince Albert. Now open to the public, this particular visit was arranged by and for a party of electronic engineers (some like PC more or less retired) and their ladies (wives, spouses, companions or partners). The house itself, of which we saw only a part, did not make much impression on either PC or his missus, apart that is from the remarkable Indian Room. However, the grounds were of more interest, and particularly some of the other buildings therein.

Apparently, the Prince was intent upon instilling a commendable habit of self-discipline and work in the royal children. To this end, there was constructed in the grounds a Swiss Cottage, complete with kitchen, dining room, bedroom etc., in which the children were trained to be able to look after guests entirely by their own efforts, bereft of the services of cooks, maids, butlers and what-have-you. Most of the rooms are now as they were then, and one of them houses an exhibition of topical items from the time. In particular, in 1870 the Anglo-Mediterranean Telegraph Company invested £440,000 in a project for the construction of telegraph cable to India via Egypt and Aden. The almost instantaneous passing of messages over such a vast distance was seen as of inestimable value in maintaining the British Empire and Commonwealth, and the exhibition includes samples of the various types of armoured cable used on the link's single circuit, which was capable of sustaining only slow speed Morse. A far cry from today's technology where Gigabytes of installed capacity send data flying over myriads of circuits worldwide, with (optical fibre) terrestrial cables coming back into favour as less vulnerable than communications satellites.

Also in the grounds at Osborne, adjacent to the Swiss Cottage, there is another wooden building, which is a Museum containing many of the artefacts that Victoria and Albert collected. The most interesting of these to PC was the original Morse-inked paper tape, received at the Newfoundland Telegraph Station, of the first translantic telegraph message. This was sent by Queen Victoria to the then US President, 16th August 1858. I suppose he replied promptly; otherwise how would she and all the important bystanders know that this newfangled contraption really worked? Presumably it wasn't *really* the first message: there must surely have been some test messages before getting the Queen and the President involved, even given the Victorians' well-known supreme confidence in their technology. Even so, Osborne is definitely worth a visit by anyone interested in the history of electronics (or in gardens, architecture, etc. etc.).

Green Power (of the Electrical Variety)

PC is always interested in a more environmentally acceptable face of technology, and an item in the IEE Review caught his eye recently. In the late '50s, a lot of research went into trying to develop a method of electricity generation which avoided the need for a separate steam-raising boiler, with the inefficiency attendant upon the Rankine cycle. One hopeful contender was MHD (magneto-hydrodynamic generation), but little ever came of it. The item mentioned above describes current work in Japan on a fuel cell using atmospheric oxygen and a phosphoric acid electrolyte. With an efficiency in the range 35 to 45%, it hardly betters steam powered stations, but being entirely silent it can be located practically anywhere. This means that its waste heat (it operates at around 200°C) can be used in a CHP scheme.

Combined heat and power schemes aim to use waste heat from the generator for process heat in industry, or space heating or whatever. Molten-carbonate fuel cells operate at efficiencies in the range 50 to 60% but their higher operating temperature of 650 to 1000°C makes design more complicated. On the other hand, in a CHP scheme, they can supply higher grade process heat. This news item was headed, appropriately, "Look, no turbines"!

Funny Talk

My competition of some months ago, concerning politically correct speech, brought in some amusing contributions. One such, pointed out that the term 'politically correct' is itself not politically correct – it should be 'differentially cognate with reality'. However, the Editor and I had no difficulty in agreeing that the following contribution is the undisputed winner:-

'My Wife' Banned

University staff have been told they can no longer say "This is my wife" when introducing spouses. The word 'my' indicates possession and is discriminatory, according to an 11-page brochure at the University of Central Lancashire. Companions should always be introduced by their full name and the 1,500 staff have been warned they could face disciplinary action if they breach guidelines. From the Huddersfield Daily Examiner, 17th March 1994.

The report does not say whether wives are permitted to refer to "my husband". If they are this is clearly a case of discrimination against men, whilst if they are not, it makes no allowance for couples who have taken conventional marriage vows whereby each agrees to own (and be owned by) the other. One wonders who is responsible for dreaming up such silliness.

Anyway, thank you M.A.C. of Huddersfield for sending in this gem of lunacy, and I declare you the outright winner of the competition. So look out, for your free year's subscription to the Maplin Magazine.

Yours sincerely,

Point Contact

The opinions expressed by the author are not necessarily those of the publisher or the editor.

3 PROJECT RATING

KIT AVAILABLE (RU36P) Price £39.95 D1

PA-1 2-Metre AMPLIFIER

The assembled 2m Amplifier ready for use.

Please note that the box shown is not supplied in the kit and must be purchased separately.

Special Precaution

Due to Beryllium Oxide being present in the SD1272 Power transistor, it is advisable to be particularly careful when fixing and handling the device.

Do not under any circumstances break open the case of this device since Beryllium Oxide is highly toxic.

FEATURES

- Boosts RF output power to 30W plus
- Automatic switching
- Easy to fit and use in mobiles

APPLICATIONS

- Use in conjunction with hand-helds
- Use in conjunction with low power base stations

Text by Robin Hall G4DVJ

These days, most radio amateurs who are active on 2m will probably have a low powered FM hand-held transceiver. This project is for those operators who need to boost the output power on 2m of such a rig.

Please note that a current radio amateur licence, either Class A or B is required before transmissions can be made on the 2m VHF band.

The assembled PA-1 2-Metre RF Power Amplifier.

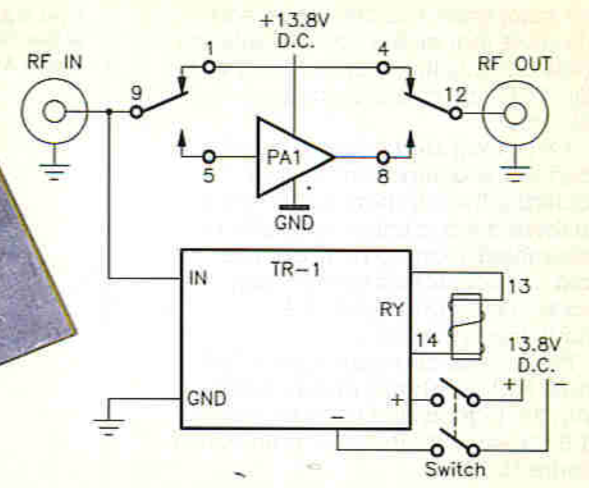


Figure 1. Block diagram of the PA-1 2-Metre RF Power Amplifier, with the TR-1 RF Activated T-R Switch.

Right: Close-up of the assembled TR-1 RF Activated T-R Switch

Important Safety Warning for Vehicle Installation

Before starting installation work, consult the vehicle's manual regarding any special precautions that apply. Take every possible precaution to prevent accidental short circuits occurring since a lead-acid battery is capable of delivering extremely high current. Remove all items of metal jewellery, watches, etc., before starting work. Disconnect the vehicle's battery before connecting the module to the vehicle's electrical system. Please note that some vehicles with electronic engine management systems will require reprogramming by a main dealer after disconnecting the battery. Assuming a negative earth vehicle, disconnect the battery by removing the (–) ground connection first; this will prevent accidental shorting of the (+) terminal to the bodywork or engine. It is essential to use a suitably rated fuse in the supply to this project. For the electrical connections, use suitably rated wire able to carry the required current. If in any doubt as to the correct way to proceed, consult a qualified automotive electrician.

TYPICALLY most 2m hand-held transceivers operate on low RF power (1 to 3W), this is mainly due to the battery pack supplied, and to the power dissipation in the power amplifier stage (PA). It is becoming more common to use a hand-held transceiver or 'handy talkie' in a mobile situation using an external mobile antenna, and some form of hands-free microphone; or in the home, where the handy talkie serves as a secondary rig such as for packet radio. The problem is that the power is rather low for these applications. The PA-1 2m Amplifier is an ideal project to be built in order to boost this power to 30W plus (the exact output power is dependent on the output power of the transceiver).

Circuit Description

Figure 1 shows the block diagram of the PA-1 and TR-1. The power to the circuitry is derived from an external 12V nominal (13·8V DC) power supply able to supply at least 5A, supplying both the power amplifier PA-1 and the transmit/receive board TR-1.

A suitable transmitter/receiver or transceiver is coupled to the 'RF IN' socket. With the relay in its de-energised state the connection is through the 'RF OUT' socket, which is then connected to an aerial or a suitable dummy load.

Specification

DC Power:	12 to 14V DC
Current consumption	
Quiescent:	5mA
Operating:	4A
Output power:	10 to 35W
Input Power for full output:	8W

The PA-1 amplifier at this stage is in its quiescent state, along with the TR-1 switch. On the action of transmitting, the TR-1 circuit senses the RF energy and the relay changes state, and a path is then made for the RF energy to be transferred to the RF input of the main PA-1 PCB. Refer to Figure 2a which shows the RF input coupled to the main amplifier device Q1 (SD1272) via the input passband components C1, C2 and L1. The DC power being obtained through L3. The output is then passed through another filter network consisting of L2, C4 and C3.

A detailed drawing of the RF sensing circuit of TR-1 and the associated relay is shown in Figure 2b. The RF energy is filtered by C1, R1 and R2 and rectified to a DC voltage by D1 and D2. The NPN transistors Q1 and Q2 which are coupled as a Darlington pair are normally switched off, but when DC is applied from D1 to the base of Q1, the transistor conducts as does Q2 and the collectors then fall to zero potential. This in turn effectively supplies the negative to the relay which is connected to the 12V supply and then switches over thus enabling the RF energy to be transferred via the PA-1 amplifier, and then out to the aerial.

The power transfer characteristic of the amplifier is shown in Figure 3. As can be seen, for 1W in, 10W out, for 2W in, 20W out and for 3W in 30W out. There is a maximum drive level of 8W, with a maximum output of between 35 and 40W, this depends on a number of factors, not least the build-quality of the project and the DC supply voltage.

Figure 4 shows the typical output to be expected at 145MHz, and the harmonics which are present. Again this is dependent on the way the circuit has been built and how clean the signal from the transmitter or transceiver is.

Construction

There are two boards to be constructed in this project, the construction details will be given for each.

Assembly of the PA-1 PCB

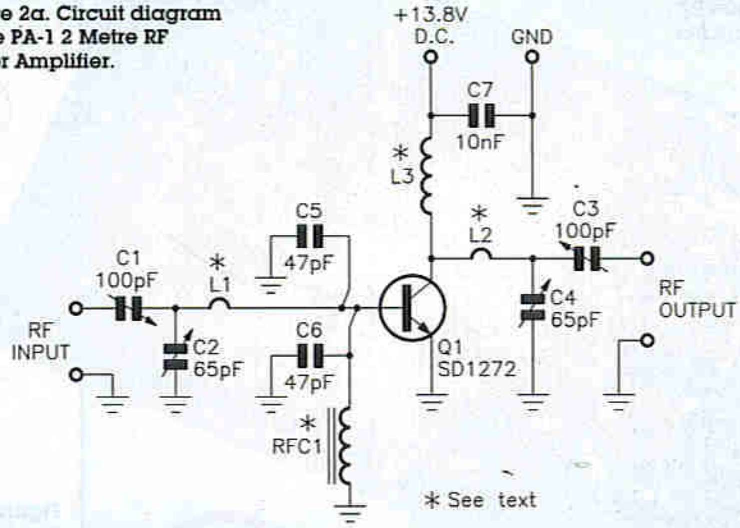
Important note: Refer to the case drilling details as it is essential that the RF power transistor is mounted to the Diecast box, *before* it is soldered to the PCB. It is very easy to damage the transistor case and break the leads. Also note that all the components are soldered onto the copper side of the PA-1 PCB, and conventionally on the TR-1 PCB.

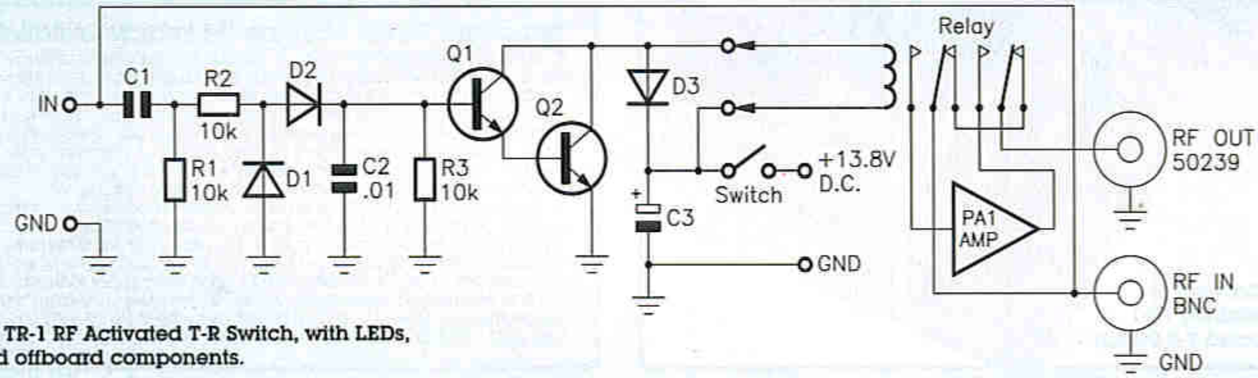
It is a good idea to sort out and identify the components before soldering them in place. In the PA-1 kit there are a number of coils to be assembled, leads to be prepared, and capacitors that require their leads to be prepared for the mounting to the PCB.

The legend and track for the PA-1 main PCB are shown in Figure 5a, with the legend and track for the TR-1 PCB shown in for the PA-1 main PCB in Figure 5b.

If you are new to project building, refer to the Constructors' Guide (order separately as XH79L) for helpful practical advice on how to solder, component identification and the like.

Figure 2a. Circuit diagram of the PA-1 2 Metre RF Power Amplifier.





2b. TR-1 RF Activated T-R Switch, with LEDs, and offboard components.

As the components are soldered directly onto the copper track on the PA-1 PCB, the leads on a number of components have to be shaped to fit.

Figure 6a, shows the modification to the two mica compression trimmer capacitors and Figure 6b to the two round trimmer capacitors. Figure 6c shows the modifications to be made to leads of the ceramic capacitors.

There are four inductors to be made, L1, L2, L3 and RFC1. For L1, cut a 1in. length of 1·0237mm tinned copper wire and form it as shown in Figure 7a. Next, use another length of 1·0237mm tinned copper wire to make L2, a 1-turn ¼in. diameter coil as shown in the side view of Figure 7b (a good former is a 5mm drill), and expand the coil by ¼in., top view. Leave ¼in. of wire free at each end.

Using 1·0237mm enamelled wire, wind a 5-turn coil for L3. The inside diameter being ¼in. (again using a 5mm drill as a former), the side-view is shown in Figure 7c, the turns should be close wound, as shown in the top view. Again leave ¼in. of wire free at each

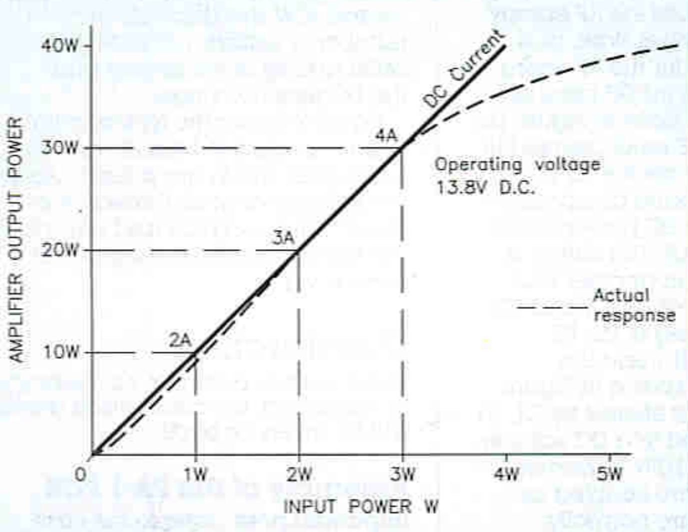


Figure 3. PA-1 2 Metre RF Power Amplifier input and output power transfer characteristic.

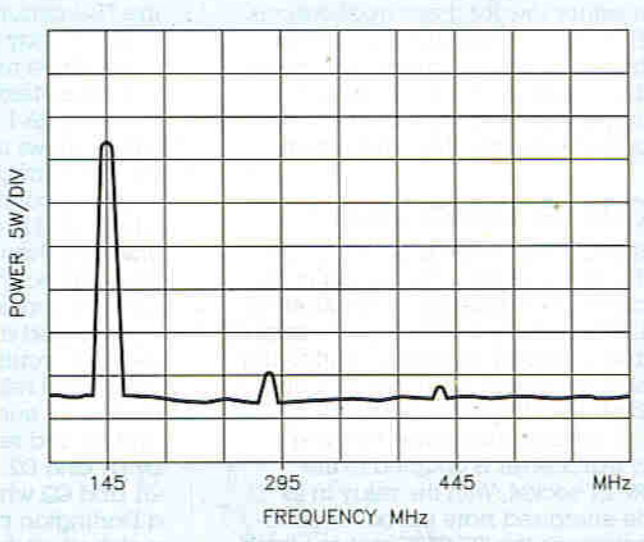


Figure 4. PA-1 2 Metre Power Amplifier power bandwidth.

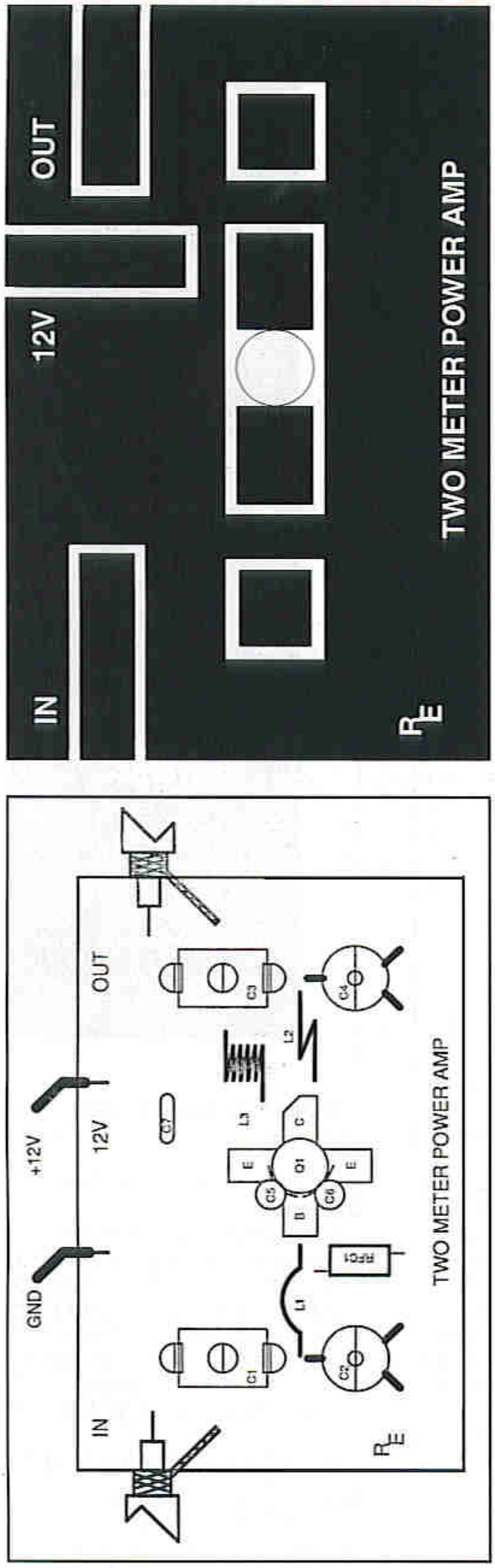


Figure 5a. PA-1 2-Metre Power Amplifier PCB track and legend ©Copyright 1994 Ramsey Electronics.

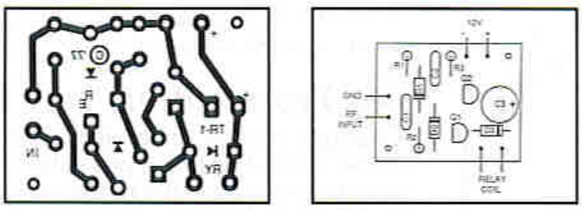


Figure 5b. PA-1 2-Metre Power Amplifier TR switch PCB track and legend ©Copyright 1994 Ramsey Electronics.

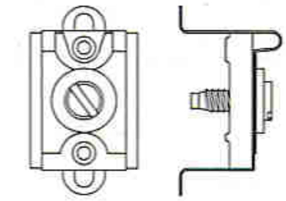


Figure 6a. Preforming C1 and C3, mica compression capacitors.

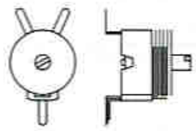


Figure 6b. Preforming the small trimmer preset capacitors.

Figure 6c. Preforming the ceramic capacitor leads.

L1 from 1" of bare wire

Figure 7a. Preforming L1.

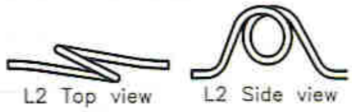


Figure 7b. Preforming L2.

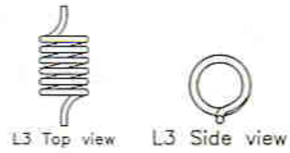


Figure 7c. Preforming L3.

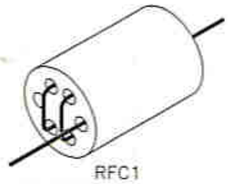
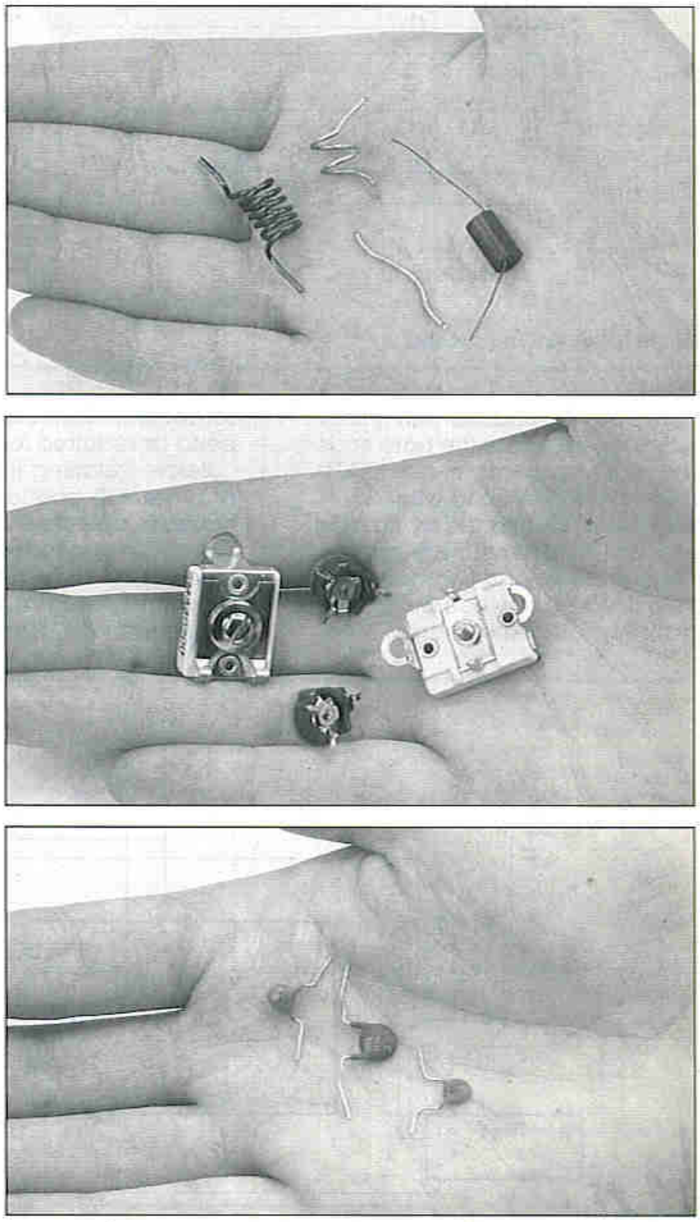


Figure 7d. Lacing 5-turns of wire through the RF choke.



The inductors, trimmers and capacitors ready for fitting onto the PCB.

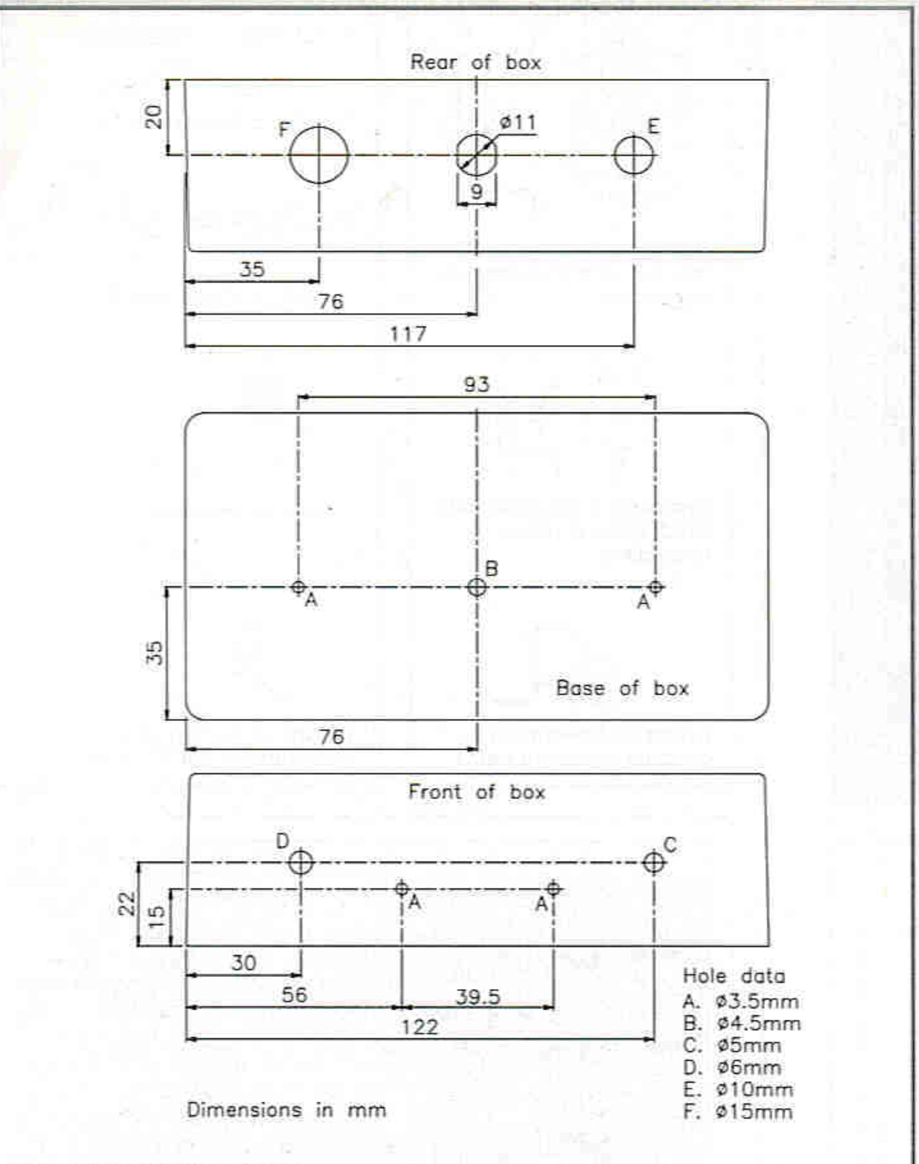


Figure 8. Box drilling details.

Figure 9. Front panel label.

end, remove the enamel with a knife or sandpaper, and tin the bare ends.

The radio frequency choke (RFC1), consists of a ferrite bead with six holes, and is constructed by passing 5 turns of the 0·510mm bare wire through each hole as shown in Figure 7d. Make sure that when pulling the wire through, that the enamel is not scraped off. Trim the ends to ¼in. and bend as required for installation.

Before installing the components onto the PCB, position the RF power transistor onto the PCB as shown in Figure 5a, and mark out how far its leads extend towards the input and output pads. It is important to note the orientation of the transistor's collector lead, this has a 45° cut to help identify the lead.

Setting the RF power transistor aside, now install the components onto the PCB, starting with the compression trimmer capacitors C1 and C3 and then the bypass capacitor C7. Next install the round trimmer capacitors C2 and C4. Next fit the three coils starting with L1 to L3 and then RFC1.

Assembly of the TR-1 PCB

The components are mounted onto the PCB in the normal manner. Refer to the circuit in Figure 2b, and the legend and track in Figure 5b. Fit the resistors and correctly orientate and fit the semiconductors. Next fit the capacitors making sure of the orientation of the electrolytic capacitor. Next fit the optional pins on the PCB, these are for the connections to the power supply, aerial, and the relay.

Box Preparation

A suitable case for the project is the LH73Q diecast box. This has to be prepared to accept the mounting of the RF power transistor, as well as the sockets the relay and switch. Figure 8 shows the drilling details of the optional diecast box, which should be

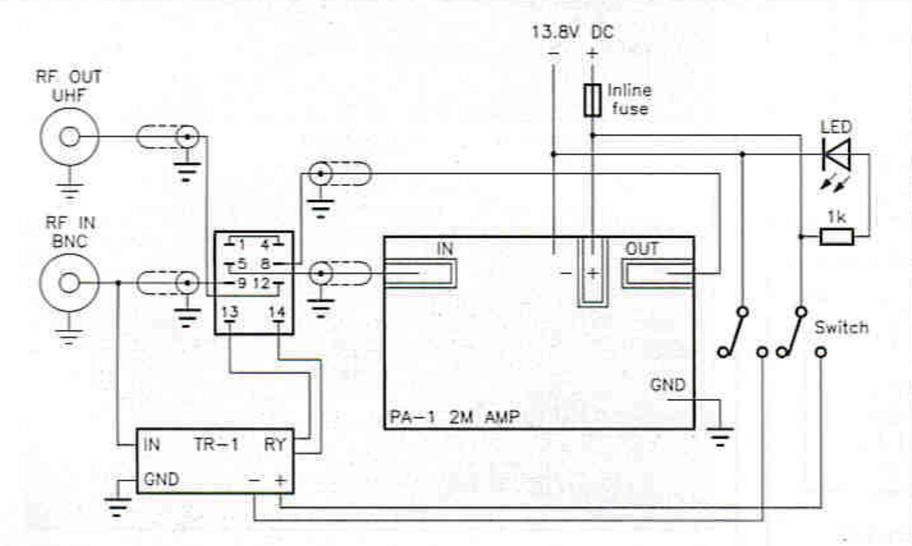


Figure 10. Amplifier wiring diagram.

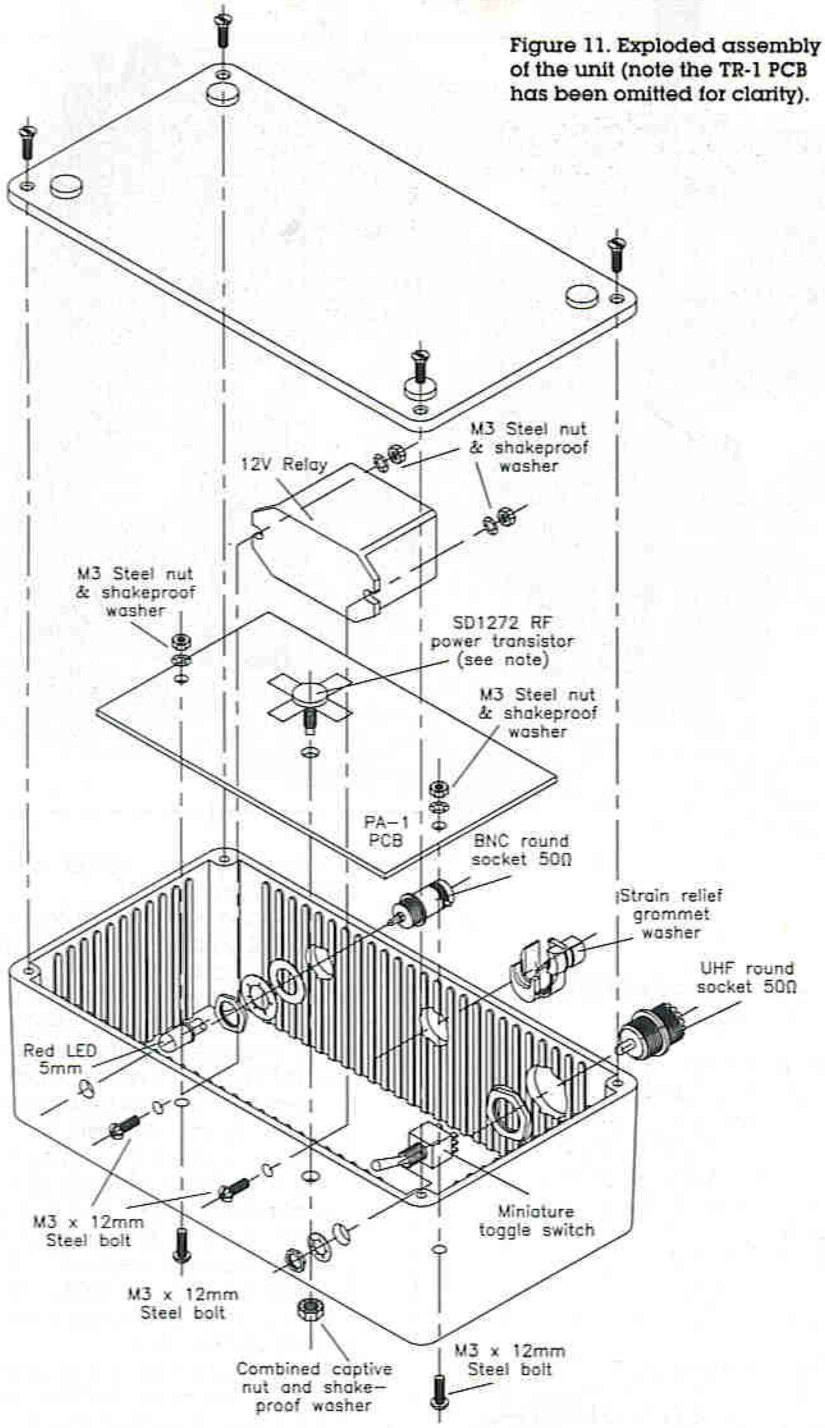


Figure 11. Exploded assembly of the unit (note the TR-1 PCB has been omitted for clarity).

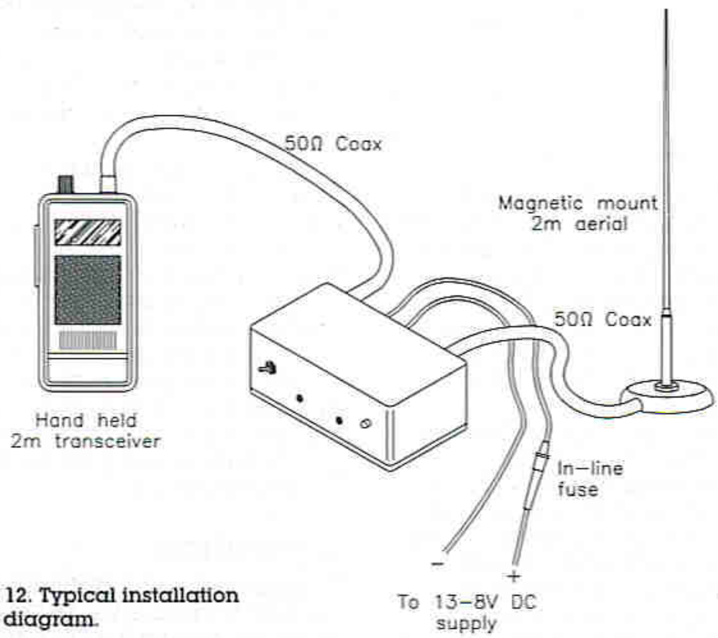


Figure 12. Typical installation wiring diagram.

drilled, filed and cleaned of all metal particles. For further support it is suggested that the PCB be drilled in the positions indicated, and fastened to the box with two nuts and bolts.

Figure 9 shows a suitable front panel label, which should be photocopied or cut out and fixed in position before fitting the switch and LED. It is a good idea to protect the label from damage bu covering it in clear adhesive film, e.g. Fablon.

Because the case is part of the heatsink for the power transistor, it is not necessary to have an external heatsink.

Final Assembly

Note: With the PCB in position this procedure must be followed implicitly, carefully mount the RF power transistor. Do not overtighten the lock-nut. Fit the two bolts through the box and PCB, and hold in position by two nuts. When you are happy that the PCB and power transistor are in position, solder the four leads on Q1 the RF power transistor to the PCB.

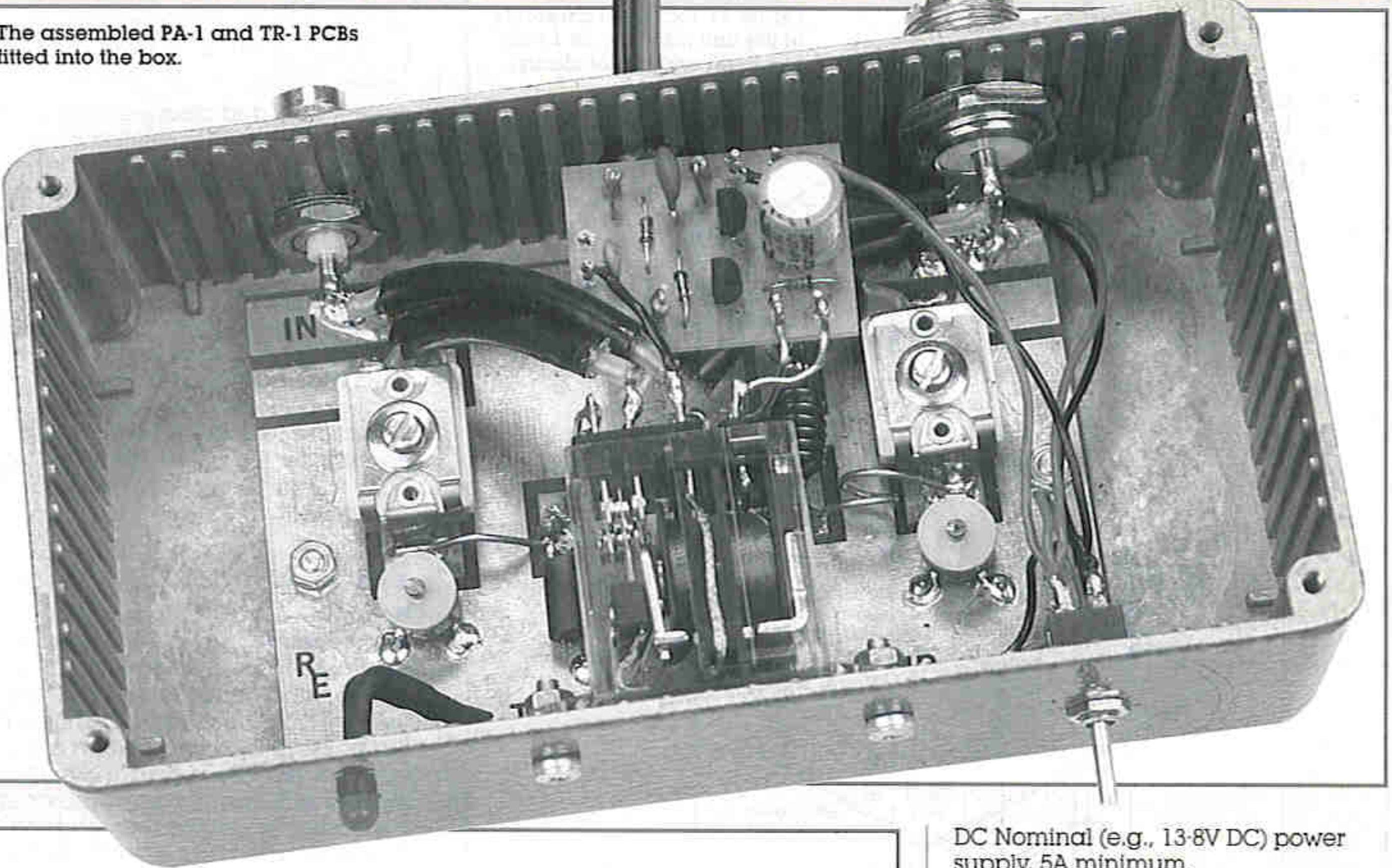
Finally fit the two capacitors C5 and C6 as shown in Figure 5a, making sure that the leads are kept short.

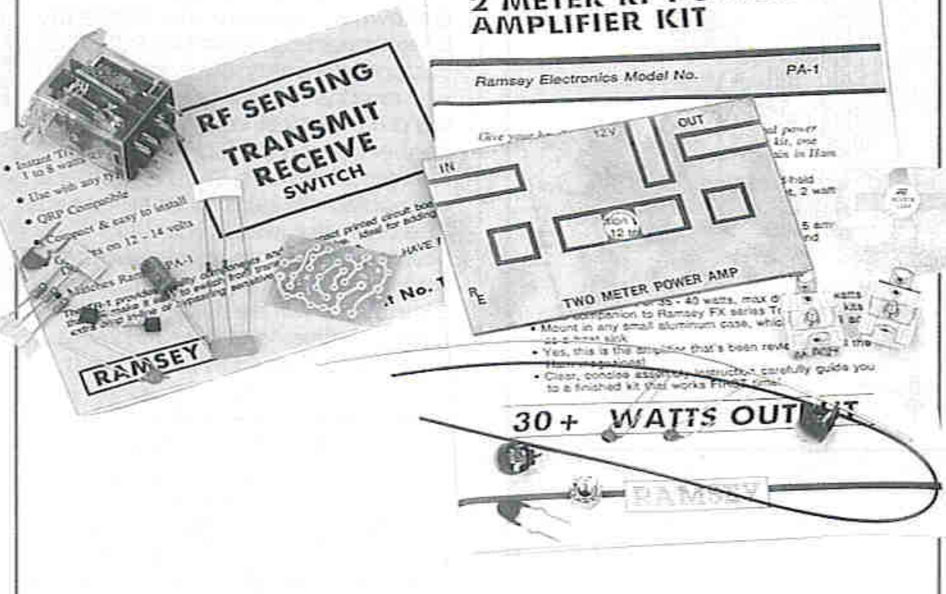
The wiring diagram for the PA-1 is shown in Figure 10. This shows the interconnection of the two PCBs, the changeover relay, the coaxial and power connections. The RF input is via a BNC socket, and the aerial connection via a SO239 socket, on the rear of the box. The 12V power is connected via suitably rated external fuse and wire, which is held in position by a strain relief grommet. Pass the wire through the strain relief grommet, it will be necessary to use a pair of pliers to fit the two halves together and position it through the hole provided in the box. Solder the wires directly to the PCB, ensuring correct polarity. The power to the TR-1 PCB, switch and LED is supplied by smaller diameter wire. Solder two 10cm lengths black and red wire to the same position as the larger diameter wire, these will be soldered to the switch on the front panel.

Fit both RF sockets, and solder the earth tags to the ground on the PCB, extending the BNC earth tag if necessary. Fit the relay into the box, and hold in position with two nuts and bolts. With a spare offcut from the 1·0237mm wire connect pins 1 and 4 together. Next cut four lengths of 50Ω coax and trim and connect up as shown in Figure 10, to the PCB and relay, and from the aerial connectors to the relay.

Next with wire offcuts, connect the two power connections 13 and 14 to the TR-1. These connections also hold the TR-1 PCB in position. Solder another offcut of wire and pass through the PCB and solder onto the ground on the PA-1 PCB. With a suitable short length of wire, connect

The assembled PA-1 and TR-1 PCBs fitted into the box.





The TR-1 and PA-1 kits as supplied.

the RF IN on the TR-1 PCB to pin 9 on the relay.

Fit the switch and the light emitting diode (LED) to the front panel (the LED on the left). Connect the LED with the smaller red and black wire (use heatshrink sleeving on the wire connections to prevent short circuits), and connect to the switch, on the same connections solder the wires from the power input. Finally connect the GND and (+) on the TR-1 PCB to the switch.

Setting Up

It is especially important that all the connections are thoroughly checked before testing the unit. So visually check, to make sure that there are not any obvious mistakes, remember you only have *one* RF power transistor.

With a multimeter set to ohms, or a continuity tester, check that there is a through connection from the RF sockets; also check the earth connections.

As most amateur radio enthusiasts have test equipment such as VSWR/Power meter, 30 to 50W, 50Ω dummy load; these should be used in testing the amplifier, along with the correct 50Ω cables and connectors.

A 2m transmitter or transceiver providing up to 5W RF power is required as well as an external 12V DC Nominal (e.g., 13·8V DC) power supply, 5A minimum.

Connect a 50Ω coaxial cable from the aerial output on the rig to the amplifier input (the majority of hand-helds now have a BNC socket as standard) and connect a 50Ω coaxial cable from the amplifier output to a suitable dummy load or aerial. Next connect the external supply to the amplifier. As can be seen, the DC voltage is applied to the amplifier all the time, this is possible as it is operating in Class C, and only draws current when RF drive is applied. With the rig on receive there should not be a significant increase in the current, if there is, switch off immediately and investigate the cause.

With the switch on the amplifier set to bypass, switch on the hand-held. Next set the transmitter to 1 or 1·5W (no more than 5W) and then press the PTT. The VSWR meter or wattmeter will indicate the power out. If there is a problem, then it will either show as very little power, or no power at all, dekey the transmitter at once and investigate the cause if this is the case.

If all is well, proceed to the final tuning. Adjust the trimmers C1 and C3 fully clockwise, and key up the transmitter. Next tune C2 on the RF input, this has the most significant control over the driving of the RF power transistor Q1. After the power output has been peaked, readjust C3 and C4 for maximum output, and then readjust C1 and C2 as required. The amplifier should produce at least 8 to 10 times power gain, for example 1·5W in for 15W out.

Operation

Disconnect the dummy load, and connect a suitable 2m VHF aerial. Next tune around the 2m band and locate any stations that are on. Once a station has been located switch the bypass switch to on, there should not be any difference in the received signal. After checking all is well at this stage, select a frequency, such as the calling channel and give a test call. If someone comes back, invite them to QSY to another frequency off the calling channel, and hopefully you will re-establish contact. Once this has been done, check the low power with the amplifier off, and then with it on. If an VSWR/Power meter has been included in the aerial lead, then switching between low and high power will show on the meter, as well as the standing wave ratio (SWR). Afterwards thank your contact.

If you are going to fit the power amplifier in a vehicle, please read the Safety Warning at the beginning of this article.

Acknowledgment

Thanks are due to Waters & Stanton of Hockley for supplying the PA-1 2m 30W amplifier and the TR-1 transmit and receive switch.

PARTS LISTS

PA-1 2-METRE RF POWER AMPLIFIER

CAPACITORS		
C1,3	100pF Mica Compression Trimmer	2
C2,4	60pF Variable Trimmer	2
C5,6	47pF Ceramic Disc	2
C7	10nF Ceramic Disc	1
SEMICONDUCTORS		
Q1	SD1272 RF Power Transistor	1
INDUCTORS		
L1,2	1·0237mm Tinned Copper Wire	1
L3	1·0237mm Enamelled Copper Wire	1
RFC1	0·510mm Enamelled Copper Wire	1
	RFC Ferrite Cylindrical Bead	1
MISCELLANEOUS		
PA-1	PCB	1

TR-1 RF-ACTIVATED T-R SWITCH

RESISTORS		
R1-3	10k	3
CAPACITORS		
C1	5 to 33pF	1
C2	10nF Ceramic Disc	1
C3	100 to 220μF Electrolytic	1
SEMICONDUCTORS		
Q1,2	2N3904	2
D1-D3	1N914/1N4148	3
MISCELLANEOUS		
	TR-1 PCB	1
	12V Relay	1

OPTIONAL PARTS LIST

1k Resistor	1	(M1K)
5mm Red LED	1	(WL27E)
UHF Round Socket	1	(BW84F)
BNC Round Socket 50Ω	1	(HH18U)
BNC Plug 50Ω	2	(HH17T)
Ultra Miniature Toggle Switch	1	(FH99H)
Stick-on Feet Large	1 Pkt	(FW38R)
50Ω Coaxial Cable	As Req.	(XS51F)
30A High Current Wire Red	As Req.	(XR59P)
30A High Current Wire Black	As Req.	(XR57M)
1·4A Hook-up Wire Red	As Req.	(BL07H)
1·4A Hook-up Wire Black	As Req.	(BL00A)
Heat-Shrinkable Sleeving Type CP24	1 Pkt	(BF88V)
In-line 1¼in. Fuseholder	1	(RX51F)
6·3A 1¼in. Fuse	1	(UJ88V)
Strain Relief Grommet	1 Pkt	(LR47B)
Aluminium Alloy Diecast Box (DCN5005)	1	(YN50E)
Single-ended PCB pin 1mm (0·04in.)	1 Pkt	(FL24B)
M3 × 12mm Steel Bolt	1 Pkt	(JY23A)
M3 Steel Nut	1 Pkt	(JD61R)
M3 Shakeproof Washer	1 Pkt	(BF44X)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available in kit form only.

Order As RU36P (PA-1 2-Metre Power Amplifier) Price £39.95 D1

Order As RU37S (TR-1 RF-sensed Relay) Price £14.95

Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

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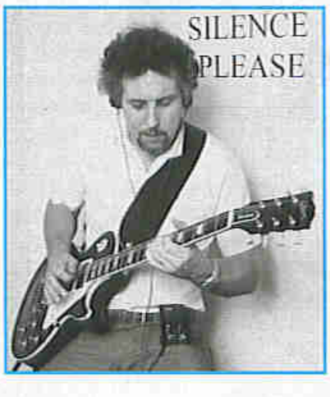

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Getting to know Test EQUIPMENT

PART 6

Automatic Test Equipment (ATE)

It used to be that the testing of electronic appliances was just a case of measuring a few independent analogue measurand parameters, such as voltage and current amplitude, frequency and time relationships etc., at a small number of points. Generally the parameters could be measured one at a time, without any problem.

Typical modern electronic appliances, on the other hand, are of a microprocessor-based system nature, and demand testing of a large number of digital and analogue measurand parameters at a corresponding large number of points. Additionally, the parameters are often so interdependent that their values only have significance when monitored in relation with each other. Thus, measurements must be taken simultaneously.

Trends in electronic test equipment naturally reflect this change, Figure 1 illustrates the general move from single time, single measurand test instruments to multi-time, multi-measurand instruments. Simple analogue and digital meters represent the basic equipment, capable of performing a single measurement at a single time. The oscilloscope extends the measurement by performing it over a period of time. Dual- and four-trace oscilloscopes allow a small number of measurements to be made over this period of time. Logic analysers take this facility two stages further, first, by allowing a large number of measurements to be made over the single period of time, and second, with recent developments in logic analysis, by allowing a large number of measurements to be made over a number of time periods. In all these instances, the user effectively controls the functions of the test instrument.

However, the trends do not stop there. As electronic appliances become ever more complex and as manufacturers attempt to build in greater levels of reliability, so the test instruments used must themselves become even more complex. The limits suggested by Figure 1 are not, in fact, test equipment limitations but human limitations. It becomes increasingly difficult to correlate all the information regarding the many measurements which modern test equipment is capable of taking and, in many instances, is even impossible. For this reason much modern test equipment is microprocessor controlled.

An instrument, say, an oscilloscope, with microprocessor control includes many different functions which, opposed to a conventional oscilloscope, are automatic. Functions such as timebase and X amplitude may be automatically controlled: the microprocessor controlled oscilloscope is an example of an *automatic test instrument*. Most modern automatic test instruments are *programmable*, that is, they feature an interface which allows their internal microprocessor (and therefore their measurement functions) to be controlled by an external computer. Most, if not all, the measurement facilities of an automatic test instrument may be set by a computer via this interface, and measurements taken are similarly relayed back to the computer for correlation and display. When a computer is used to control one or more programmable automatic test instruments the resultant system is what we know as *automatic test equipment* (ATE). This difference is important: automatic test instruments are devices capable of performing and displaying measurements autonomously or in a system; automatic test equipment is a complete measurement system, consisting of one or more automatic test instruments and a computer controller.

Such automatic test equipment requires computer control to ensure correct operation, record the measurements, and correlate the vast amounts of measurement data, presenting it in a form readily understood by the human user. In effect, the user no longer *directly* controls the test equipment (although the user must still program the computer which *does* control it), and most, if not all, functions are automatic.

Measurements are not limited by the user: any number of different measurements can be performed in any number of time periods. For example, the user of an analogue voltmeter has great difficulty in taking and recording even one measurement a second. Programmed automatic test equipment could take, record and display as many as one thousand measurements in the same time. Alternatively, automatic test equipment could take and record one measurement every second for the next thousand days – non-stop and accurately (without food, drink or sleep!).

Basic Methods of Automatic Test Equipment

There are two basic methods of creating automatic test equipment. First, a unique device may be designed and made, specifically for the purpose. Figure 2 shows an example of such a device, capable of taking a number of measurements of voltage and current, while counting events, measuring frequency, distortion and frequency response, and monitoring signals on a data bus. Output from the device to the system under test is a swept sinewave signal. Control of the various measuring facilities is provided by the microprocessor-based heart of the device, which in turn is controlled by programmed instructions from the user. This type of automatic test equipment is, in fact, a computer system complete with the necessary input and output units to allow measurements of the various parameters of the system under test. Recording of the values of these parameters and the format of the correlated information again depends on the user's programmed instructions, and is displayed either on a monitor or hard-copied onto paper with a printer.

The second method of creating automatic test equipment is to use a microprocessor-based personal computer, and use it to control general-purpose test equipment such as meters, universal counter timers, logic analysers, signal generators etc., as if they were peripheral devices, as illustrated in Figure 3. In this method each piece of test equipment performs the measurements it is told to do by the computer on the system which is being monitored; then relays the readings to the computer, which records and displays the correlated data, again on a monitor or printed onto paper. As in the first method,

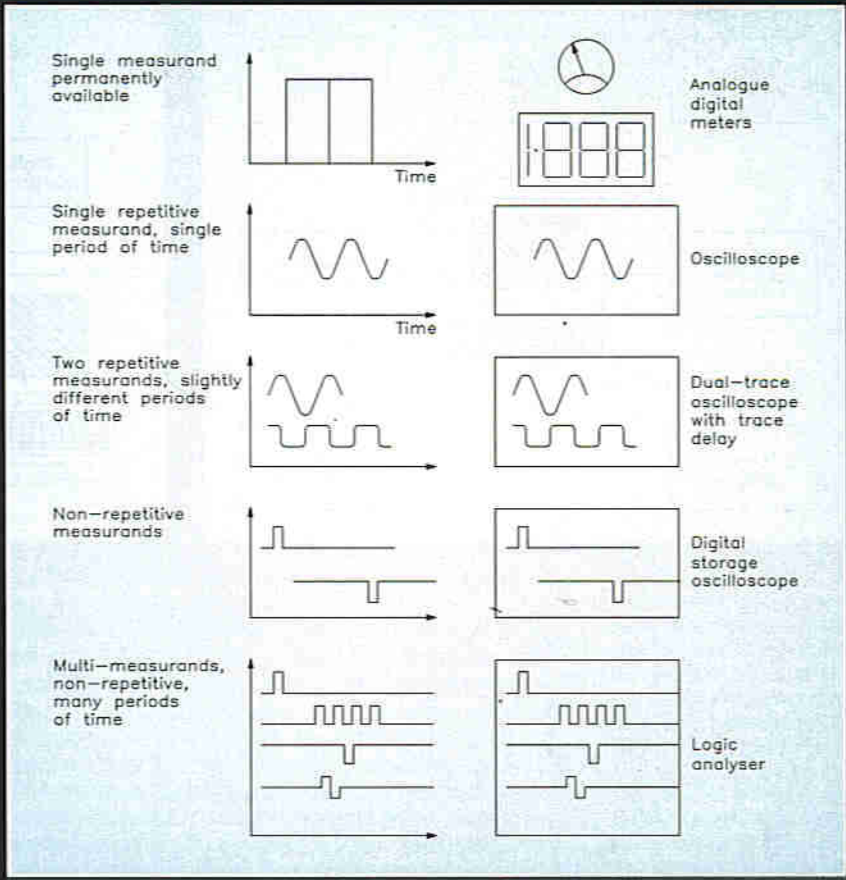


Figure 1. Suitable test equipment, such as the analogue digital meter, oscilloscope, dual-trace oscilloscope with trace delay, digital storage oscilloscope and logic analyser.

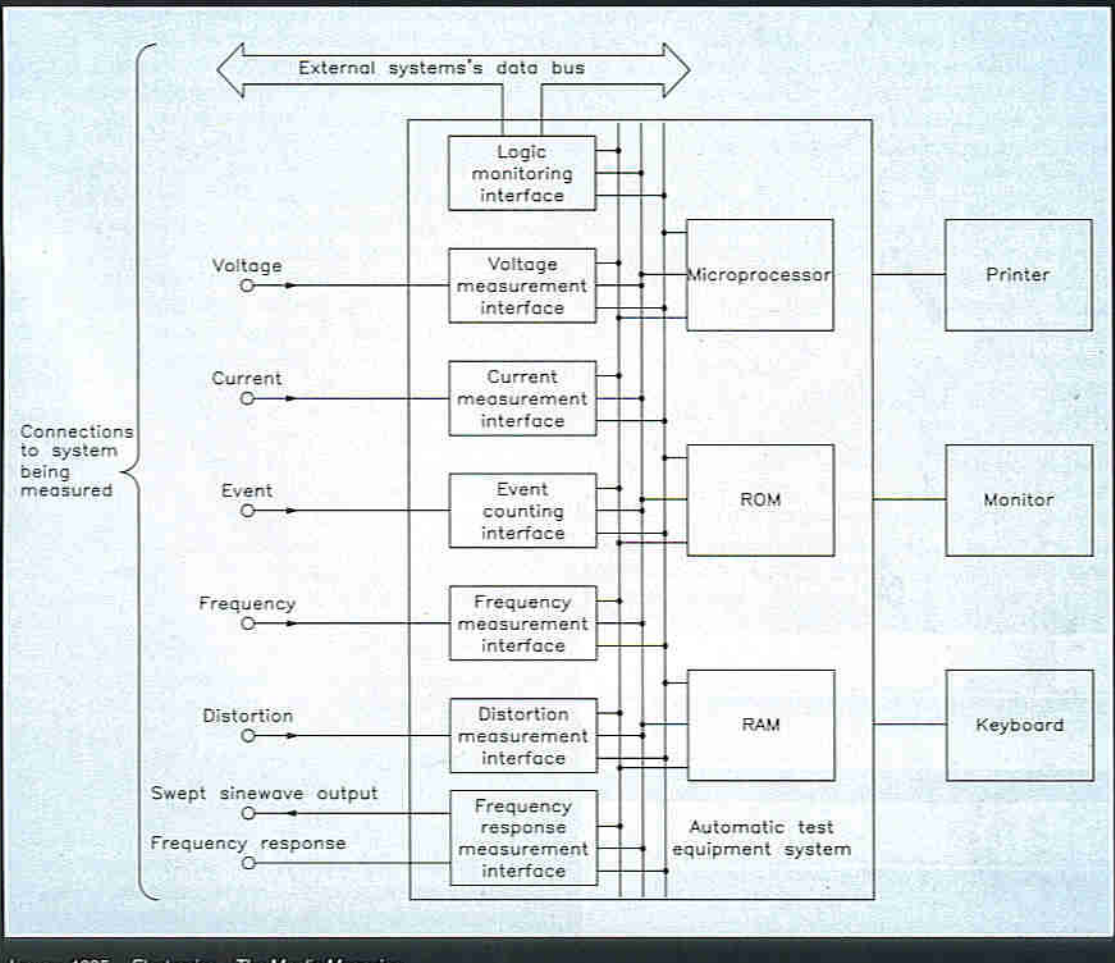
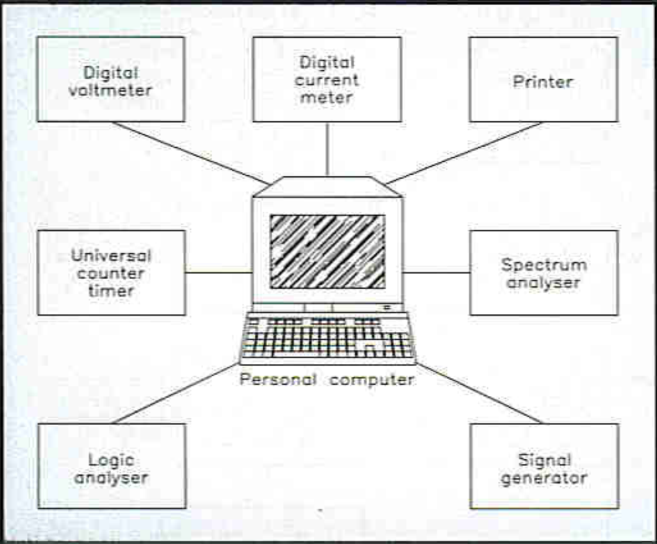
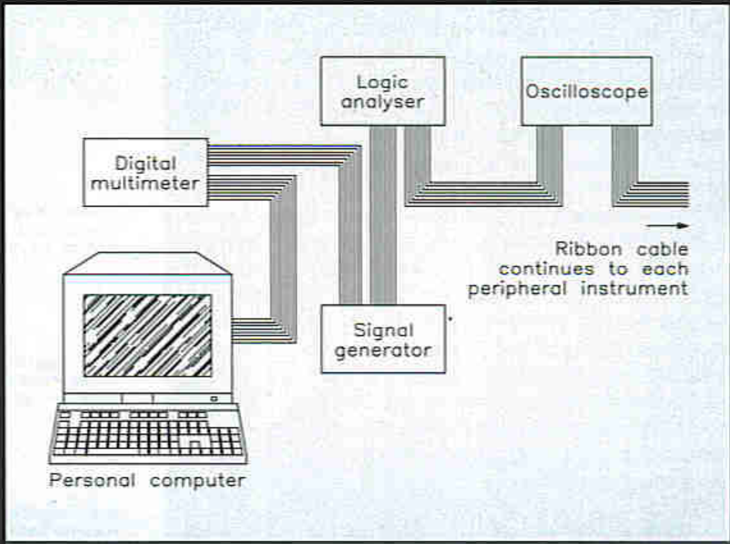


Figure 2. This shows an example of a device, capable of taking a number of measurements of voltage and current, while counting events, measuring frequency, distortion and frequency response, and monitoring signals on a data bus.





Above: Figure 3. Using a microproprocessor-based personal computer to control general-purpose test equipment such as meters, universal counter timers, logic analysers, signal generators.

Above right: Figure 4. Linking a number of instruments to a common data and control bus, and controlled by a personal computer.

the user controls the overall system operation with programmed instructions.

From these descriptions it is fairly obvious what the main differences between the two methods are: the first is a custom-built *device*, which is likely to be quite expensive in terms of initial capital outlay, can only be used to test one particular system, and will most probably be used to test electronic appliances which are manufactured in vast quantities; the second is a custom-built *system*, which is still very expensive, but can easily be adapted to suit other test applications, so will most probably be used to test electronic appliances which are manufactured in quite small quantities (with the knowledge that the system can also be adapted to suit other applications, as and when necessary). In practice even the first method can usually be adapted, as a modular design approach is often used which allows the user to change measurement modules to suit other applications, and the two methods are simplified representations of extremes of automatic test equipment design philosophy. The philosophy, of course, is simply one of having a variety of test instruments which are controlled by a computer which, in turn, is controlled by a user's program to suit the test application.

If a number of instruments are to be controlled by a computer, it makes sense if each instrument's interface links to a common data and control bus, as in Figure 4. A bus structure makes the system very flexible as extra instruments can be added with little fuss. When automatic test equipment began to be constructed the first common bus was the general-purpose interface bus (GPIB), which was developed into the European standard IEC625; also known as BS6146 in the UK and IEEE488 in the USA. More recently, its place has been taken by the faster and more capable VXIbus (a development of an existing computer bus – VMEbus). Most manufacturers conform now to VXIbus, although many others do exist.

Fixtures

Between automatic test equipment, and the unit under test (usually an assembled and soldered PCB, before packaging in its housing) some form of *fixture* needs to be used. Fixtures adapt any particular automatic test equipment system, allowing it to be used with any product.

Below: Typical spring contact probes (CSP):
(a) Concave type (UL99H).
(b) Convex type (UM00A).

Generally, fixtures are designed to allow tested products to be connected and disconnected from the automatic test equipment system rapidly and easily. Thus, after each individual product is tested it may be removed and the next product installed in the minimum of time. In high-volume production areas, mechanical, robotic handlers are often used to install PCBs into fixtures, remove them, and install the following boards. Consequently one of the aims of fixture design must be to make installation and removal of tested boards as straightforward as possible.

Typically fixtures have large numbers of probes sited in a flat surface, and each probe is positioned to locate a point on the printed circuit board corresponding to a required circuit node. As the board is pressed onto the fixture the probes make electrical contact. For obvious reasons such fixtures are known as *bed-of-nails* fixtures and, typically, use spring-loaded probes which allow a measure of mechanical compliance while ensuring electrical contactability. Vacuum-actuated bed-of-nails fixtures (where an air pressure reduction on one side of the board holds it in position) are most common. Generally, test point probes are matrixed on fixed centres of 2·54mm (0·1in.), though sometimes a closer grid of 1·91mm (0·075in.) or 1·27mm (0·05in.) centres are used (occasionally centres of 0·63mm – 0·025in. – are used to provide fixtures for small substrates of extremely high component densities).

Probes

Typical probes used in such fixtures are known as *spring contact test probes*, and one is illustrated in Figure 5, comprising a barrel, a plunger and a spring. The barrel is crimped to prevent the plunger from coming out. Working travels of probes are between about 1·2mm (0·05in.) and 8mm (0·01in.), and probes are selected according to PCBs being tested.

Metals used in probe parts vary. Plungers are most often of heat-treated beryllium copper, turned to an accuracy of $\pm 5\mu m$ (0·0002in.). These are then electroless nickel-plated, then gold-plated. Occasionally, rhodium plating is used instead of gold, giving a harder finish; desirable for some applications.

Barrels and receptacles are drawn from nickel silver, often preplated or alloyed with gold, although phosphor bronze or beryllium copper are sometimes used where stronger parts are needed.

Spring material depends more closely on requirements: beryllium copper is used for lowest electrical resistance, stainless steel for high-temperature applications, while music wire is used for highest spring force.

Receptacles

Probes are used with *receptacles* which are permanently mounted into the fixture; a probe pushing simply into a receptacle, as shown in Figure 6. Receptacles are permanently positioned and wired into a fixture, and various

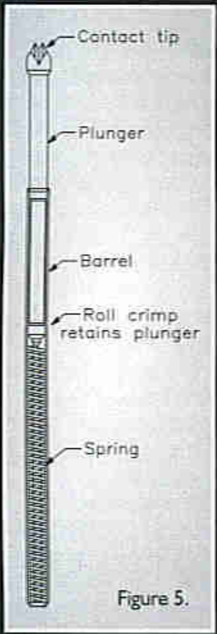
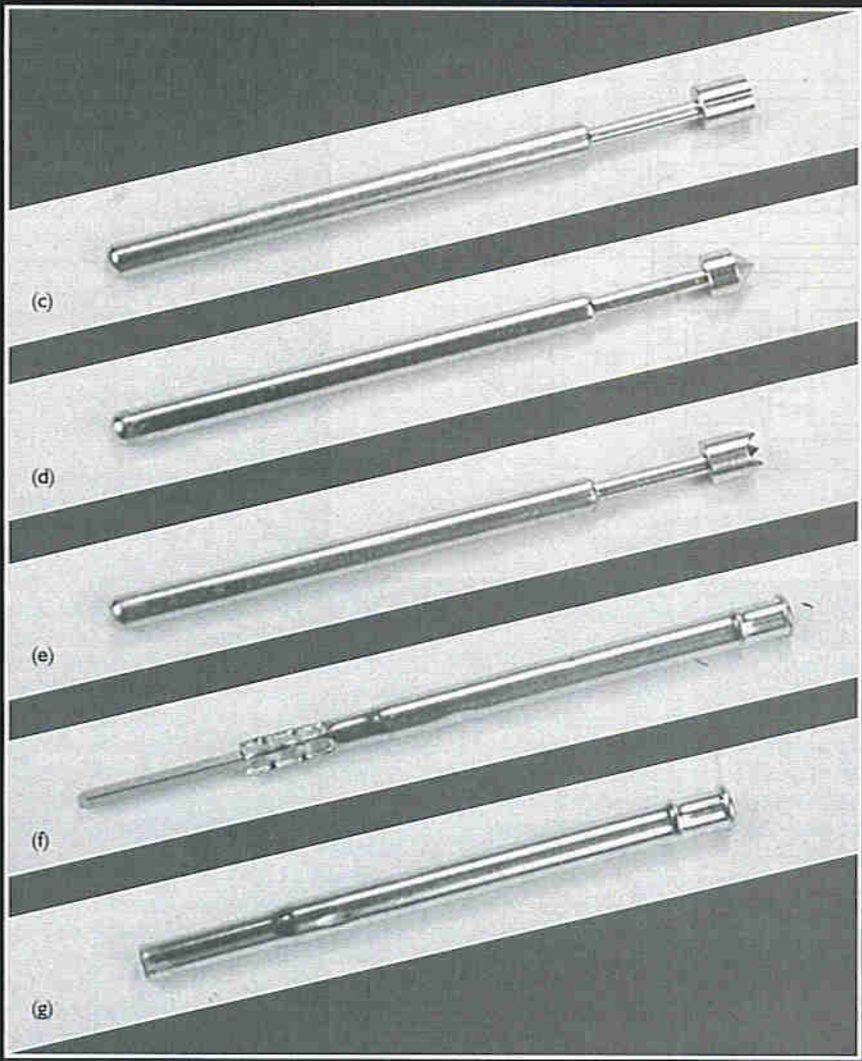


Figure 5.



P-series PCB Test Jig system contact probes:
(c) Concave type (UM01B).
(d) Convex type (UM02C).
(e) Toothed type (UM03D).
(f) A square pin projection receptacle for holding probes (UM04E).
(g) A circular pin projection receptacle for holding probes (UM05F).

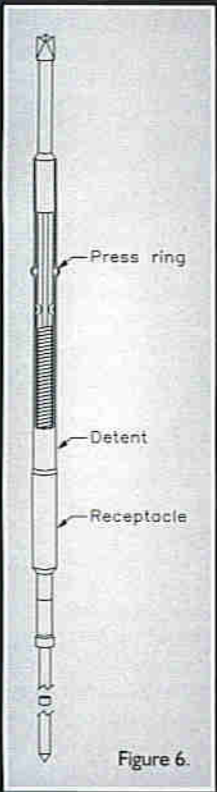


Figure 6.

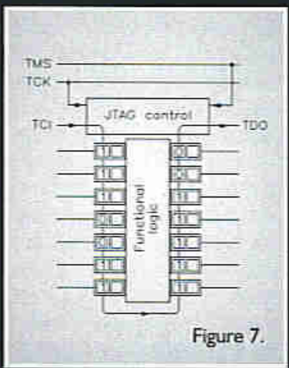


Figure 7.

Figure 5. A typical *spring contact test probe.*

Figure 6. A probe used in a permanently mounted fixture.

Figure 7. A scan test integrated circuit, with test clock (TCK), test mode select (TMS), test data in (TDI) and test data out (TDO).

wiring termination styles (push-fit, solder, crimp, wire-wrap and so on) are used to suit specific applications. Such a push-in arrangement allows probes to be changed without trouble of rewiring or disturbing a fixture. One or more *detent crimps* in the receptacle side holds the probe into position while a fixture is in use and allows electrical contact between probe and receptacle.

Receptacles are generally held in place by internal press-rings in the wall, which collapse as they are pushed into a fixture hole. This fitting method requires a fixture plate of sufficient thickness. Alternatively, where plates are too thin, fixture holes may be slightly larger, and press-rings are then used as a simple shoulder to prevent it falling through the fixture. In such cases receptacles should always be glued in position.

Test Strategies

Of course, mounting the PCB in its fixture is just a mechanical task. More important is the electrical test consequently undertaken. First, most PCBs consist of many (sometimes many hundreds of) individual components; each of which needs to be tested. Second, the whole PCB needs to be tested as a complete product.

These two test strategies are often followed separately, but sometimes can be carried out on single automatic test equipment. The first is known as *in-circuit testing*, and is where the bed-of-nails fixture really helps. By having access to internal parts of the circuit via the probes, it is possible to individually test each component to check it works properly. Tests are often carried out serially (each component at a time), but some equipment is capable of carrying out several tests in parallel. If any particular test fails, the component at fault is immediately known. In-circuit testers (ICTs) are often also known as manufacturing defects analysers (MDAs), simply because component failure is a manufacturing defect.

Testing the complete PCB as a whole product is known as *functional testing*. While not giving an indication of the particular component which is at fault, it tends to be a more rapid test.

Combinational testing is where the automatic test equipment is capable of performing both in-circuit and functional tests together.

Design for Testability

These basic test strategies are not, on their own, able to solve all test problems if products are complex and miniaturised circuits, where access to all circuit nodes is impossible. Very large scale integrated (VLSI) products and, specifically, surface mount component (SMC) assemblies which both may feature extremely dense circuits do not always allow total nodal access with test point probes. This trend towards miniaturisation using such assembly methods is accelerating, too; a fact which will cause more problems as time progresses. Already it has been determined that, while in-circuit testing of small scale integration (SSI) to medium scale integration (MSI) detects nearly all possible faults, only around 85% of faults in LSI, and somewhat less than 75% of VLSI faults may be detected by in-circuit means. Also, programming requirements and test times both rapidly become excessive as products increase in

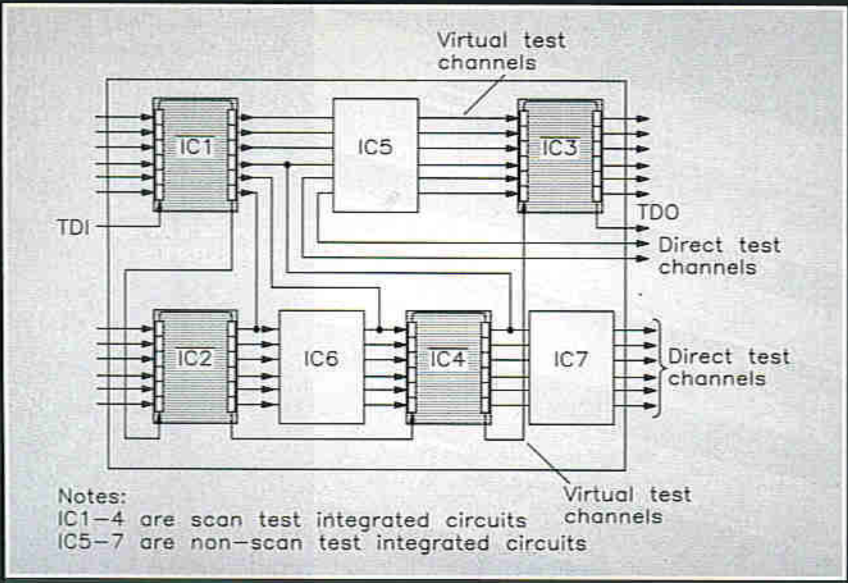
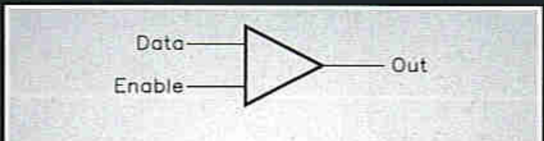


Figure 8. Scan test ICs alongside non-scan test ICs.

circuit density and complexity, with a consequent and dramatic cost difference.

With this in mind manufacturers and designers are turning their attention, on a wider scale, to building certain features into their products to allow following test stages to be undertaken more easily and, even more important, with greater effect and more cheaply. In the main, these features are intended to allow *partitioning* of tested circuits into smaller functional blocks.

Generally, inclusion of such features is called *design for testability* (DFT) which, by the fact of its virtue in aiding product testing, is a form of test strategy in its own right.



Data	Enable	Out
1	0	Hi–z
0	0	Hi–z
1	1	1
0	1	0

Figure 9. A TTL driver with its truth table.

Scan Test

Scan testing is just one example of design for testability, which uses special ICs capable of being switched into a test mode. These have a test mode in which internal input and output latches are all connected together to form a shift register, known as the *scan register. Scan in* input and *scan out* output pin connections, directly to and from the register, are also provided, and scan tests on individual ICs are often called *internal scan tests.*

Scan testing an IC with a scan register can merely entail scanning a test pattern vector into the register, returning to normal operation for a defined number of cycles (usually one) then re-establishing test mode and scanning out the resultant vector from the register. Other test pattern vectors may be scanned in and out to test individual functions of the IC, but the overall process is as simple as this single test stage shows.

Scan input and output pin connections of ICs within a whole product may be linked together, forming a complete scan register around the circuit. Because of this, a circuit design using scan test devices is also known as a *boundary scan* design. With boundary scan design a complete circuit's test process can, in effect, be as simple as scanning in a single input vector and observing the output vector. Vector output pattern immediately allows determination of faults, isolating particular ICs where faults have occurred. In practice, many vectors need to be scanned in and out if sequential logic elements are in circuit.

A scan test IC is shown in Figure 7. Four connections to the IC are common and so it forms what is known as a *four-wire testability bus.* Two control signals: test clock (TCK) and *test mode select* (TMS), together with scan register in and out connections *test data in* (TDI) and *test data out* (TDO), make up the bus. A simple connection of one integrated circuit's TDO output to the following one's TDI input allows test information to be scanned through both.

Scan test design is useful because its very presence effectively breaks up a circuit into device-sized partitions during test. Direct physical access to devices, with nodal test point probes for in-circuit test strategies, is not required. This means device-level testing of miniaturised products, in the form of VLSI circuit and SMC assemblies, is immediately catered for and easily undertaken if all devices in assemblies are scan test devices.

Built-in Self-test

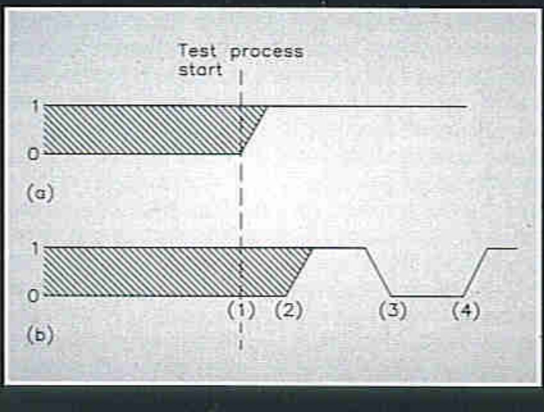
Scan test techniques can reduce requirements of complex test patterns generated by automatic test equipment, but does not eliminate them. For this reason, integrated circuit designers are currently proposing a number of additions of internal tests for ICs. Such tests are called *built-in self-tests* (BISTs) and many schemes are already available, following many methods.

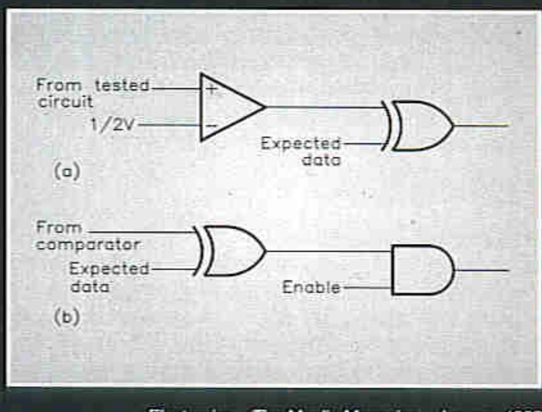
One of the most common built-in self-test methods, incorporated into several schemes, uses two *linear feedback shift registers* (LFSRs) in addition to main functional circuits within an IC. First linear feedback shift register generates a sequence of test pattern vectors which is applied to the main functional circuits, while second generates a signature from the resultant output. Basic signature analysis procedures within the automatic test equipment compares these signatures with expected results to verify correct operation or detect if an IC is faulty.

In such ICs with built-in self-test, these linear feedback shift registers will normally double as scan registers for use in scan test. Coupled with scan test, signatures are naturally routed as test pattern vectors directly to the automatic test equipment.

Mixed Test Requirements

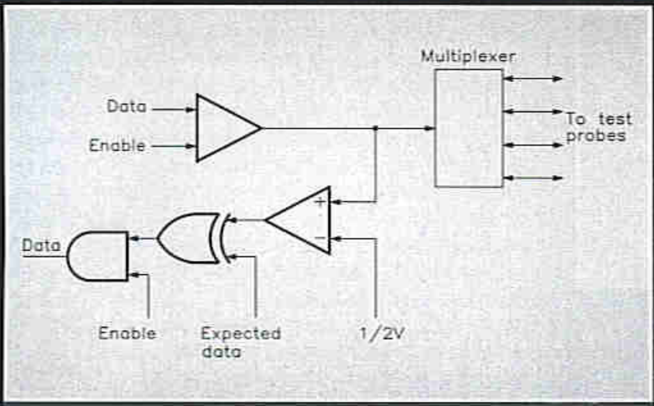
From the automatic test equipment point of view, most test requirements for the foreseeable future are going to have to deal with tested circuits comprising IC devices of scan test, conventional and, perhaps, built-in self-test designs. Coupled with these ICs will be non-integrated active and passive components such as resistors, capaci-

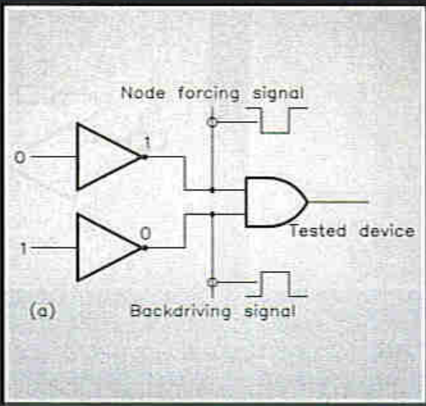




Right: Figure 10.
(a) A simple output waveform from a driver.
(b) An output from a formatted driver.

Far right: Figure 11.
(a) A simple comparative type receiver.
(b) Error signal gating from an exclusive OR gate.





Far left: Figure 12. Drivers and receivers interfaced via multiplexed circuits to the circuit under test.

Left: Figure 13. (a) A node forcing and backdriving configuration.

tors, coils, and semiconductors like transistors and diodes. Although scan test strategies provide a means of simplifying test procedures for dense scan test design circuits, which would otherwise not be able to accommodate in-circuit bed-of-nails fixture probes, it is not immediately apparent how dense mixed boards of scan test, conventional, and built-in self-test designs will benefit.

Fortunately, however, techniques are currently being developed which use scan register output vectors to allow observation of non-scan test components.

Figure 8 shows a potential PCB arrangement, with scan test ICs alongside non-scan test components. The very fact an interface occurs between the two component types means access is possible to signals around the non-scan test components. In effect, signals at each interface between scan test components and non-scan test components may be held by scan registers on the scan test components, and scanned out to the automatic test equipment system. Thus clusters of non-scan test components are isolated with these *virtual test channels*, and may be tested by standard means.

Partitioning

One of the key concepts of testability in automatic test equipment systems is isolation of tested circuit devices or parts from the remainder of a circuit. This is known as *partitioning* and, as parts within an isolated partition are often known as a cluster of parts the process is often called *cluster testing*. Partitioning is extremely useful because those parts within a cluster are viewed as if they are by themselves – not in the total circuit. Tests may be performed on the cluster as if it is an isolated circuit. Thus, a cluster is checked for operation and verified, prior to consideration as part of the whole circuit.

Partitioning relies on the ability of the automatic test equipment system to electrically isolate a partition from its surrounding circuit. How this is done depends largely on whether a digital circuit or an analogue circuit is being tested.

Digital Testing

An automatic test equipment system for testing digital circuits typically contains a set of parallel digital drivers, outputs of which are used to stimulate the tested circuit in a defined way. Results of these stimuli are monitored using a set of digital receivers.

Drivers are usually three-state devices; allowing high states and low states to be driven, as well as an undriven high impedance state. Often high and low state voltages are of standard TTL levels, although programmable state voltages are available. A possible driver is shown in Figure 9 along with its truth table.

A simple output waveform from such a driver is shown in Figure 10a, where the output is in an undefined state (one of its three possible states), then is driven high as a test process begins.

Often, however, such an output is too simple and some kind of *formatted output* is required. Figure 10b shows output of a *formatted driver* where a number of distinct stages occur in an output signal: (1) the test process begins, at which time driver output is in an undefined state; (2) output is driven high; (3) output is driven low; (4) output returns high. Effectively the driver's output is modulated by data from the automatic test equipment system's controlling program. This example shows modulated data in a *surround by complement* to zero (SBC-0) format. Other format alternatives include *surround by complement to one* (SBC-1), *surround by high impedance* (SBZ), *return to one* (RTO), *return to zero* (RTZ), *and non-return to zero* (NRZ).

Formatted drivers are used in automatic test equipment systems to impose stresses on a circuit's input timing specification. To this end, driver formats of an automatic test equipment system are often programmable and switchable by the controlling program. To further enhance this facility automatic test equipment systems often allow rise and fall times of drivers to be specified under program control. Thus, formats and rise/fall times may be varied either before or during tests.

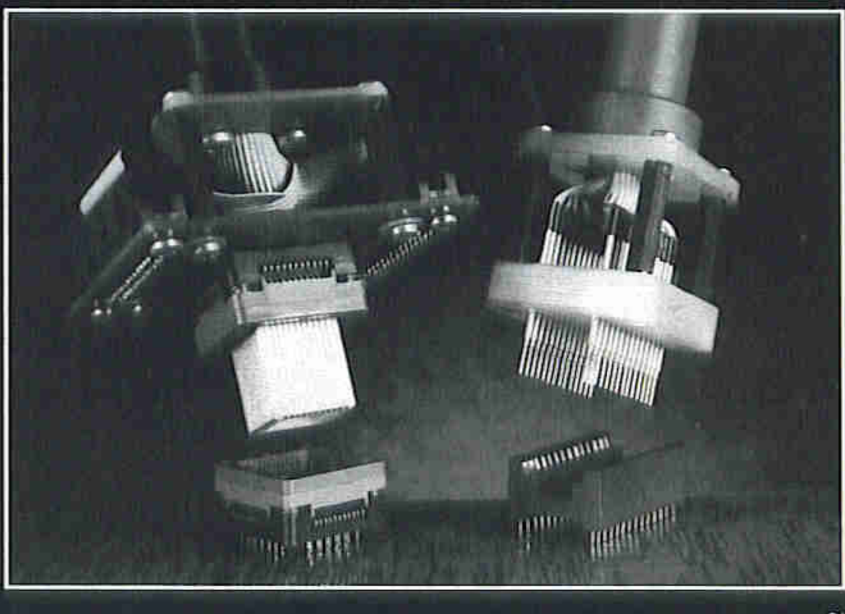
Imposition of timing stresses has a dual function. First, devices in the tested circuit are stressed to their timing limits. Second, these stresses are imposed at a much lower speed (hence a much lower clock rate is used) than would normally be possible.

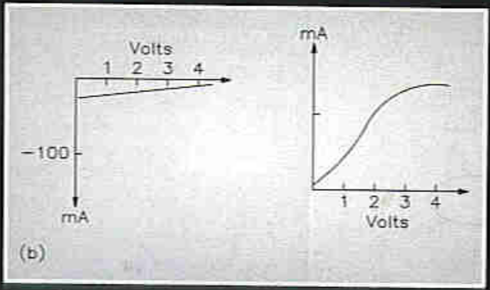
Where a fixed logical state output is required of a driver, pull-up or pull-down resistors are usually provided, switched to suit high state or low state.

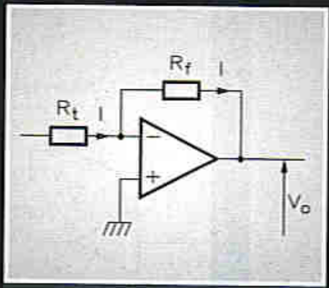
Digital receivers used in automatic test equipment systems are combinations of basic comparators (of an analogue nature, incidentally) coupled with logic gates to determine whether received data is as expected. Figure 11a shows such a simple receiver. A comparator compares the received data voltage with a defined reference voltage, giving a result which is combined with the expected data in an exclusive OR gate. When data received is the same as data expected gate output is low. However, when received and expected data are not the same, gate output is high, indicating error.

Error results may be used in several ways, generally depending on automatic test equipment system designer's ingenuity. For example, by further gating the error signal from the exclusive OR gate, as shown in Figure 11b, it is possible to define one or more windows during which a

PLCC test probe block from Peak.







Above: Figure 13.
(b) Comparison of node forced and backdriven signals.

Above Right: Figure 14. Operational amplifier operating in inverting mode.

circuit's response to driven stimulus is sampled. Then, by varying sampling delays and periods under program control, circuit response times such as data set up time, data hold time, propagation delays and so on may be measured.

Drivers and receivers are usually interfaced with a tested circuit via a multiplexing arrangement, illustrated in Figure 12. This allows a greater number of test probe access points (i.e. pins) on the tested board. So, automatic test equipment with say, 100 driver/receivers may have a multiplexing ratio of 4:1, allowing up to 400 test probes. Effectively each driver/receiver has four test probes to stimulate and monitor. Sequentially switching between test probes is therefore necessary.

Such multiplexing can give automatic test equipment a cost advantage when compared with others having a lower multiplexing ratio. However, multiplexed automatic test equipment may not allow a sufficiently large number of test points for a given application to be measured simultaneously in real-time. Following the example just given, of 400 test probes multiplexed to 100 driver/receivers, a single integrated circuit with over 100 pins simply cannot be monitored in real-time.

Switching between driver/receivers and test probes is usually performed with electromechanical relays, which feature a very low on-resistance. Relays, however, place a limiting factor on multiplexing rate. Semiconductor switches which could operate at significantly higher rates have a much higher on-resistance, which would affect measurements taken so aren't often used. Some automatic test equipment, however, features both relay and semiconductor multiplexing. Here, relays are used for accurate, but slow, measurements, while semiconductor switches are used for simple measurements (such as open and short tests) where speed is required but not accuracy.

Electrical Isolation

Where individual devices or parts in a tested digital circuit are to be tested they may be effectively electrically isolated from the remainder of the circuit, for short periods of time at least, by forcing outputs of preceding circuit devices to required logic states. If precautions are taken this may be done with no damage.

Circuit devices are effectively overwhelmed by this technique, so control of following circuit parts may be assumed by the automatic test equipment system, rather than by the tested circuit. Inputs to the selected circuit part are controlled solely by the automatic test equipment system and, in essence, the circuit part acts as if it is disconnected from the whole circuit. It is this concept which allows in-circuit and combinational testers to partition tested circuits into clusters or individual devices.

Forcing outputs in such a process is known as *overdriving* and two different modes of operation are necessary. First, if an output is high and is forced low the process is called *node forcing*. Second, a low output forced high is known as *backdriving*. Component loading when node forcing is considerably lower than when backdriving. Figure 13a illustrates use of node forcing and backdriving, where two of an integrated circuit's output stages are overdriven by signals from automatic test equipment. Graphs of node forced and backdriven signals are compared in Figure 13b. Current out of an output stage during node forcing is seen to be much lower than current in during backdriving. Node forcing is made further irrelevant when you consider its effect: forcing a high output low is the same as simply applying a short circuit on the output, which most if not all modern integrated circuit devices are designed to handle, anyway.

Overdriving preceding circuit parts to control a following circuit part does not always, guarantee absolute control. Where output of the controlled circuit part is commoned with other circuit part outputs, those other circuit parts may affect operation of following circuit parts, so must be controlled too. Such a situation often arises where digital feedback loops around counters are in a circuit. Typically, *digital guarding* is used, simply injecting fixed logic states at vital points in the circuit part, to stabilise following circuit parts thus ensuring a known state.

Overdriving is carried out using high current pulses of low energy and short duration. Two specific types of pulses are used: short pulses used to overdrive data bits, clocks and reset signals; longer pulses used to overdrive device enable, set and clear signals.

Analogue Testing

Analogue testing techniques follow, broadly at least, similar considerations as digital testing techniques. Analogue tests are normally performed using a sensor arrangement based around an operational amplifier (although impedance bridge techniques are occasionally used). Generally, non-inverting amplifier input is connected directly to ground potential, shown in Figure 14, where feedback from output to inverting input exists, which means the operational amplifier amplifies in inverting mode. In such a circuit, given ideal conditions, two operational amplifier properties are useful:

- input resistance is infinite – put another way, no current flows into the operational amplifier, therefore output voltage V_O is independent of output load. Instead, current from the tested circuit I flows through the feedback resistor R_F
- voltages at each operational amplifier input are equal; inverting input is said to be at *virtual earth*.

Output voltage of the circuit is given by:

$$V_O = I \times R_F$$

Thus measurement of output voltage gives direct indication of tested circuit analogue parameters.

Two test circuits are derived from that in Figure 14, in which the tested component is located in either the measurement amplifier's input circuit or feedback circuit, shown in Figures 15a and 15b.

Voltage Forcing

Figure 15a shows a circuit in which a resistor R_T is tested by applying a voltage V_T across it, which by Ohm's Law creates a current It through it:

$$I_T = \frac{V_T}{R_T}$$

which causes an output voltage from the measurement amplifier circuit:

$$V_O = I_T \times R_F = \frac{V_T \times R_F}{R_T}$$

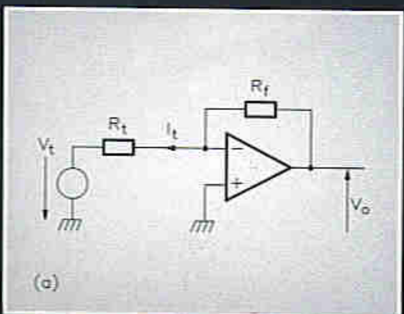
So, the tested resistor value is:

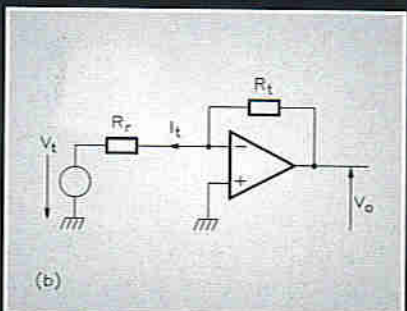
$$R_T = \frac{V_T \times R_F}{V_O}$$

Inverting this gives:

$$\frac{1}{R_T} = \frac{V_O}{V_T \times R_F}$$

Below: Figure 15.
(a) Test circuit where the tested component R_T is located in the measurement amplifier's input circuit.
(b) A similar test circuit, where the tested component R_T is located in the measurement amplifier's feedback loop.





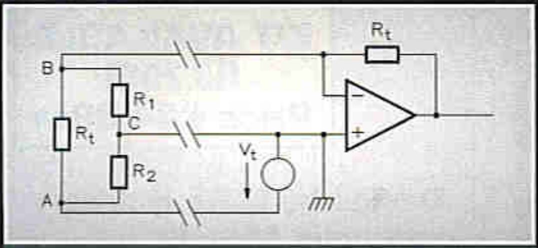


Figure 16. A simple guarding circuit.

which shows measured output voltage to be proportional to the tested resistor's admittance, so this measurement circuit is commonly called an *admittance measurement* circuit. Sometimes, because a known voltage is applied across the tested resistor, it is called a *voltage forcing* measurement circuit.

Current Forcing

Figure 15b shows a similar circuit, in which a resistor R_T is positioned in the measurement amplifier's feedback loop. A voltage V_T applied to a reference resistor R_R causes a current It through the feedback resistor, causing an output voltage: $V_O = I_T \times R_T$.

But, as $I_T = V_T/R_R$, then:

$$V_O = \frac{V_T \times R_T}{R_R}$$

and so tested resistor value is:

$$R_T = \frac{V_O \times R_R}{V_T}$$

As measured output voltage is effectively proportional to impedance of tested components, this measurement circuit is commonly known as an *impedance measurement* circuit. Sometimes, because a known current is forced through a known resistor, it is called a *current forcing* measurement circuit.

Electrical Isolation

In simple *two terminal measurements*, sometimes known as a *two-wire measurements*, shown so far, it is usual to apply a voltage to a tested impedance and measure resultant current through it using an operational amplifier. Accuracy of measurement relies totally on there being no additional current into or out of the operational amplifier measurement circuit. Where components are measured in isolation out of circuit this is possible, but in most cases components are in circuit – so other voltages and currents exist which will cause incorrect measurements of component values.

Circuits used in automatic test equipment systems to counteract other in-circuit voltages and currents, effectively allowing individual components within a circuit to be electrically isolated from the remainder – rely on a principle of nulling currents around the tested component by connecting all surrounding nodes to the same potential, allowing the measurement circuit to make an accurate measurement. There are many forms of such isolating circuits, all known as *guarding circuits*.

A simple guarding circuit is shown in Figure 16 to illustrate the guarding principle. Tested resistor R_T is shown in parallel with two other resistors R1 and R2, together forming a network. Effectively, there are three nodes in the tested network: A, known as the *force node* or the *stimulus node* as voltage from the automatic test equipment internal measurement circuit's voltage is forced onto or stimulates that point; B, known as the *sense node* or the *measurement node* as current through the test resistor R_T is sensed from or measured at that point; C, known as the *guard node* as the guard earth voltage is applied to that point.

Node B is connected to the inverting input of the operational amplifier, so is at virtual earth. Node C is connected directly to earth. Consequently, in theory at least, no current flows through resistor R1. Node A is connected to the measurement circuit's voltage source so current through the tested resistor R_T is sensed by the operational amplifier, giving a true measurement within limits. Current through resistor R2 does not affect measurement accuracy.

As this circuit has three connections between measurement circuit and tested component circuit, it is known as a *three terminal measurement* circuit or *three-wire measurement* circuit.

Limits imposed on measurement accuracy are defined by what is known as *guard ratio*, which is the ratio between current flowing in the guard path (between ground node and sense node – through what is termed the *interfering resistor*; resistor R1 in this example) to current flowing in the measurement path (between force node and sense node – through the tested resistor). From this definition, it doesn't take a genius to calculate the guard ratio is given simply by the ratio of tested resistor value to interfering resistor value (R_T:R1).

Three-terminal measurement circuits are only accurate with a guard ratio of no higher than about 100:1, which means a tested component with an interfering component of less than about a hundredth of its value cannot be measured accurately. Thus if an interfering resistor has a value of 100Ω, resistors of more than 10kΩ cannot be accurately measured.

Where higher guard ratios are required of measurement circuits, the answer is usually to resort to additional and separate sense connections at tested network nodes – to allow compensation of voltages dropped along one or more of force, sense and guard node connections. To this end, *four terminal measurement* also known as *four-wire measurement* uses a separate sense connection to the guard node. Similarly, *five terminal measurement* also known as *five-wire measurement* has separate sense connections to force node and sense node. Finally, *six terminal measurement* also known as *six-wire measurement* uses separate sense connections to each of the three nodes.

Six terminal measurement gives guard ratios of 10000:1, much improved over – that of three terminal measurement. However, every node participating in six terminal measurement requires two operational amplifier measurement circuits, and two test point probes. E

NEWTON STEREO VALVE PREAMPLIFIER

PART:2

Power Supply Unit

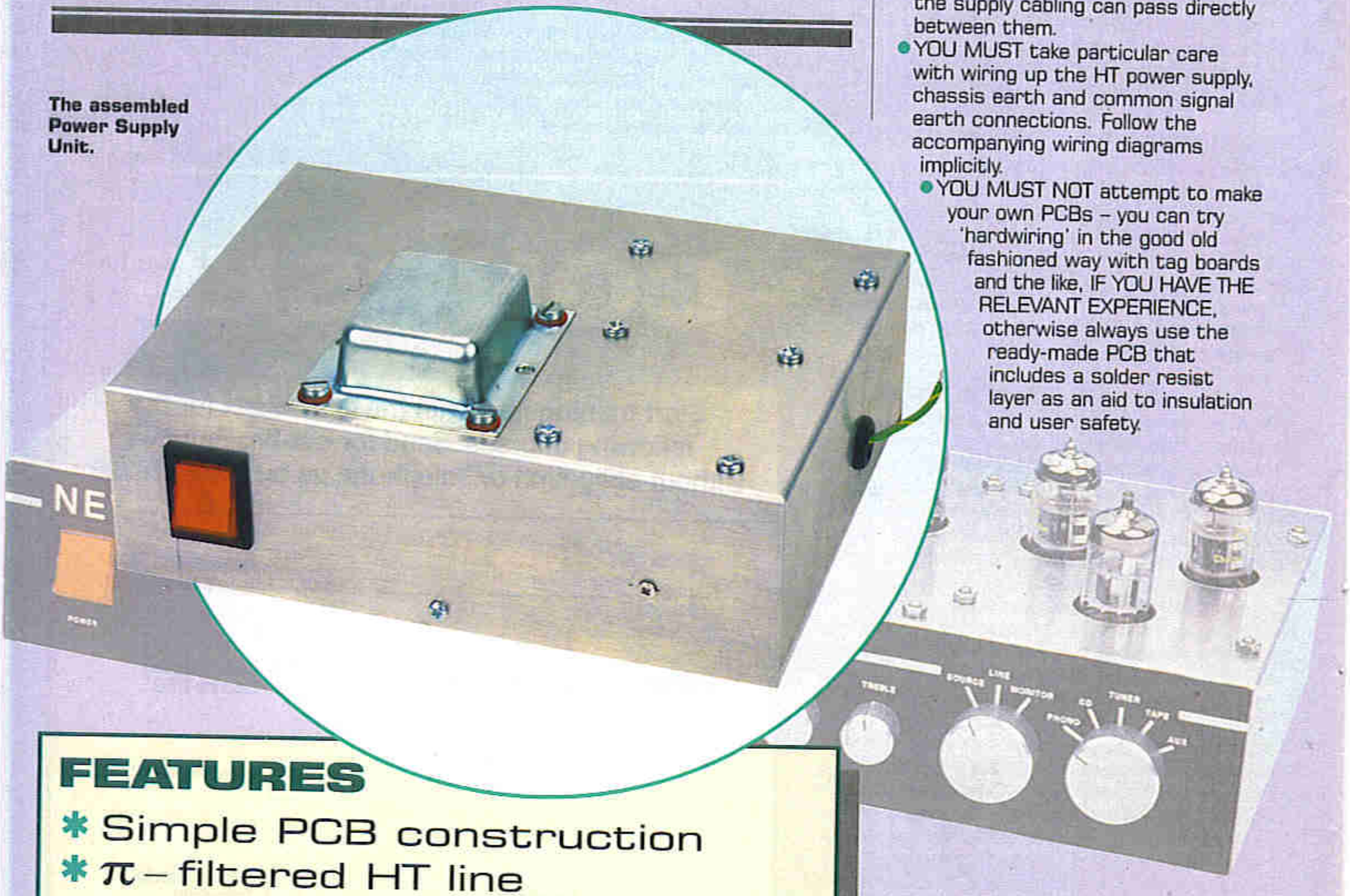
KIT AVAILABLE (LT75S) Price £44.99 B4

Design by Mike Holmes and John Mosely
Text by Mike Holmes

Earlier in this issue Part One described the RIAA Phono Module of the 'Newton' all-valve preamplifier. This part describes the Power Supply Unit.

To reiterate, a word of warning before you start.

- YOU MUST only use parts from the kit, and build it strictly according to the instructions.
- YOU MUST install the amplifier module PCBs in a fully enclosed and earthed chassis. The Phono Module Kit includes a 4 × 8 × 2·5 inch chassis, into which both this and the Tone Control PCB can be fitted if desired. Such a chassis must be physically joined to the PSU so that the supply cabling can pass directly between them.
- YOU MUST take particular care with wiring up the HT power supply, chassis earth and common signal earth connections. Follow the accompanying wiring diagrams implicitly.
- YOU MUST NOT attempt to make your own PCBs – you can try 'hardwiring' in the good old fashioned way with tag boards and the like, IF YOU HAVE THE RELEVANT EXPERIENCE, otherwise always use the ready-made PCB that includes a solder resist layer as an aid to insulation and user safety.



The assembled Power Supply Unit.

FEATURES

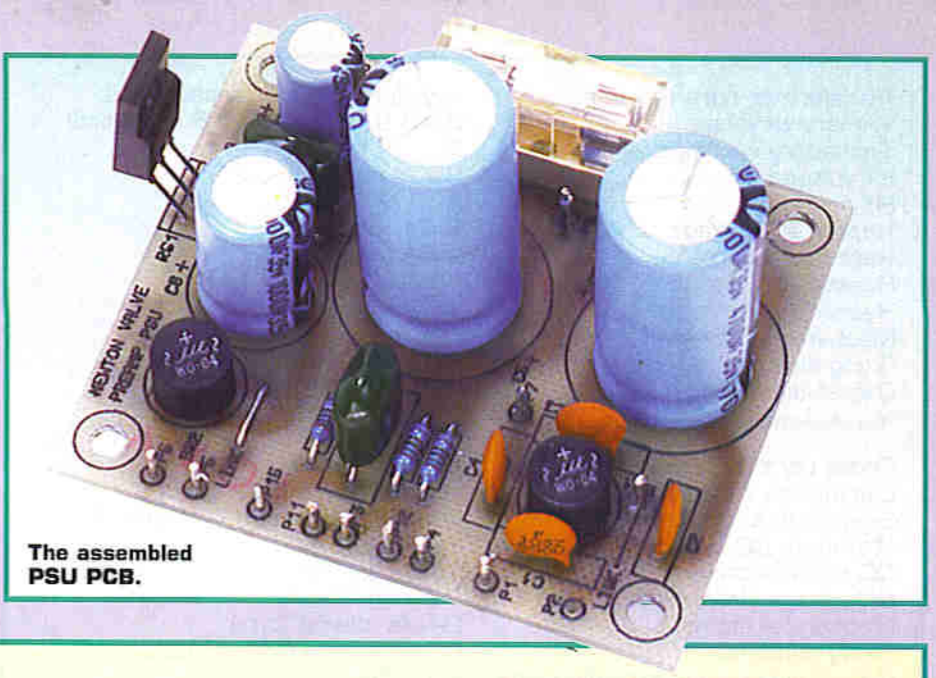
- ✱ Simple PCB construction
- ✱ π – filtered HT line
- ✱ AC and DC heater supplies
- ✱ UK and US mains compatible

4 PROJECT RATING

The Power Supply Unit

In Figure 1 of Part One, it can be seen that, derived from the mains input, the PSU module produces three different outputs. These are the main HT supply common to all valve circuits, a conventional 6·3V AC heater supply, which will be used by the phono module's line driver and the tone control module, and a special 12·6V regulated DC heater supply specifically for the phono preamplifier valves only. (See also Tables 1, 2 and 3.)

Figure 1 shows the complete PSU circuit diagram. Many of the components are contained on the single PCB, except a couple that are 'hardwired' to T1 (TS1 & C11), and the choke L1.



The assembled PSU PCB.

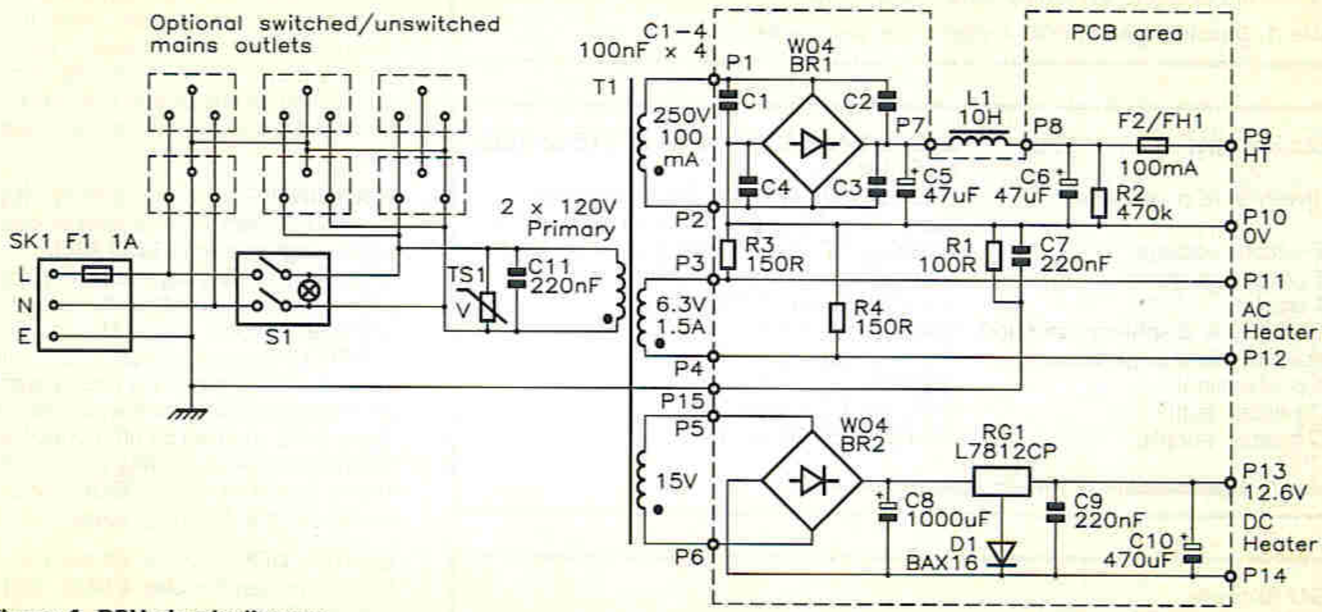


Figure 1. PSU circuit diagram.

Mains transformer T1 has a 'dual-standard' primary voltage capability, depending on how its two primary windings are configured. Hence the PSU can be built for the UK/European mains standard of 220 to 240V AC (nominally 230V AC) 50Hz, or for the USA/North American mains standard of 110 to 120V AC (nominally 115V AC) 60Hz. Mains power enters the PSU chassis via SK1, a fused and filtered Euro-style mains inlet socket, and is switched by double-pole neon switch S1. Optional Euro-facility mains outlets may be added, connected on one side or the other of S1 depending on whether unswitched or switched outlets to ancillary equipment are required. With the choke in place there may be space on the rear panel of the chassis for up to four such sockets, however, DO NOT attempt to install these if you have had no experience of fitting them or you are at all unsure of your proficiency at mains wiring! If you do use them then also use the protective insulating 'boots' (see optional Parts List).

At T1 primary there is also included a voltage transient or 'spike' suppressor, TS1, and a 220nF polypropylene capacitor C11. These, together with the filtered mains inlet, may seem like 'overkill' but having experienced excessively noisy mains I feel they are not out of place. (The prototype even has a second filter block following the inlet filter.)

On the secondary side, the 250V AC winding feeds a bridge rectifier block BR1, which includes noise suppression capacitors C1 to C4, developing unregulated DC HT on the main reservoir C5. All these components are on the PCB, but a break is made at this point to include the choke, L1, the output side of which goes to C6; together these two form an integrator or LC low-pass filter to minimise the 100Hz ripple voltage.

Return of the LF Choke

For non-critical audio usage (that is, it is not a test instrument, for example) HT 'stabilisers' are not strictly necessary, and if there is sufficient supply decoupling then any level fluctuations manifest themselves as very slowly changing transitions at the output, at a subsonic level below the AF range. If signal coupling capacitors are just small enough in value then not even much of this will be seen at the output.

Hence, it is only really necessary to reduce the ripple, which can be quite a nuisance, but at the same time not lose any more HT level than we can help, it being rather hard to come by as it is, given the unavoidable losses in the transformer.

In the valve heyday, a typical supply electrolytic was the 'double-plate' type, effectively two capacitors in one can sharing a common negative side, and between the anodes a choke was connected. The arrangement was very common and employed LF chokes in large numbers. In Figure 1, the HT supply from C5 is carried to C6 via the choke L1; the choke is chassis mounted and connected in circuit by wire to PCB pins P7 and P8. If the 100Hz ripple (a rounded, ramp shaped waveform) on C5 is 10 to 12V peak (typical), then it is reduced to the order of approximately 70mV – at least <100mV – after passing

Transformer core material:	Low-field grain-oriented steel
Primary windings:	2 × 115V (dual UK/US standard)
Secondary windings:	3
HT voltage:	350V max.*
HT current:	100mA max.*
Heater #1 voltage:	6·3V
Heater #1 current:	1·5A max.
Heater #2 voltage:	15V
Heater #2 current:	1·5A max.
Mechanical fittings:	4-bolt top cover and frame
Fixing centres:	64·5 × 52mm (4 off)
Overall dimensions:	80 × 66 × 70mm high
*Not available simultaneously.	
Choke core material:	Electrical steel
Lamination distribution:	Insulated 'E' and 'I' groups
Specific inductance:	7 to 10H nominal @ 50mA DC
Maximum DC (wire rating):	100mA
DC resistance:	150Ω approx.
DC voltage drop:	7·5V @ 50mA
Mechanical fitting:	2-hole 'clamp' type
Fixing centres:	67 to 75mm (M4 or 4BA)
Overall dimensions excluding lugs:	60 × 52 × 49mm high

Table 1. Specification of PSU transformer and choke.

Input voltage:	230 to 240V AC @ 50Hz, or 115 to 120V @ 60Hz
Primary side protection:	500mA (UK) or 1A (US) 'quick-blow' fuse, inline filter and noise suppression
HT output voltage:	<300 to 350V max. (dependent on load)
HT output current:	up to 50mA nominal, 100mA max.
HT ripple:	<100mV peak @ 50mA
HT reservoir discharge method:	Leakage resistor
Reservoir discharge time:	1 minute approx.
HT protection:	100mA 'quick-blow' fuse
AC heater supply:	6·3V @ 1·5A max.
DC heater supply:	12·6V @ 500mA max.

Table 2. Specification of Power Supply Module.

PSU Module Pin No.	**Function**
P1	250V AC in #1
P2	250V AC in #2
P3	6·3V AC in #1
P4	6·3V AC in #2
P5	15V AC in #1
P6	15V AC in #2
P7	HT stage 1 out to L1
P8	L1 in to HT stage 2
P9	+350V DC HT output
P10	HT 0V and AC heater common 0VE
P11	6·3V AC heater #1
P12	6·3V AC heater #2
P13	+12·6V DC heater output
P14	DC heater 0V (–)
P15	Chassis earth

Table 3. PSU Module PCB pin designations.

through L1 to C6. This is a reduction factor of 100 times (40dB) minimum, yet, with a 50mA drain from C6, the total voltage drop across L1 is only 7·5V DC.

Now much less noisy, the HT at C6 is available from pin P9 via protective fuse F2, housed in a covered, PCB mounting fuseholder FH1. R2 is a safety resistor ensuring that the HT line is discharged in the absence of a load or if F2 goes open circuit. The HT supply common earth is at P10, and this point is connected to chassis or mains earth at P15 via R1 and C7. R1 is a 'hum-loop block' if other audio equipment connected to the 'Newton' shares a mains earth with a signal earth via the mains lead and the screens of audio leads, the loop being completed at the PSU module. R1 is of sufficiently low value to blow F2 should a short circuit occur in the HT supply connections.

The 6·3V AC heater supply is available at pins P11 and P12. A winding centre-tap is emulated by resistors R3 & R4, tying it to 0V (P10). The heater supply thus forms two opposing, equal and opposite waveforms of 3·15V each balanced either side of 0V. When the heater supply wires are formed into twisted pairs, the opposing electric fields cancel, and these techniques reduce hum injection into sensitive areas to a minimum.

Even this may not be quite enough for the very sensitive phono preamplifier stages, so a better approach is adopted, exploiting a modern regulator IC. The valve heaters can be operated in series, so a smoothed and regulated 12·6V DC supply is provided by BR2, C8, RG1, C9 & C10, from a 15V AC winding of T1. Designed for 12V, the output of RG1 is raised to 12·6V by inserting diode D1 in its common (0V) connection. This supply is self-contained and electrically isolated from the others, meant to behave, as far as is possible, like a noise-free battery connected to the phono module only. More details about this will emerge later on.

WARNING! Before proceeding with any kind of work on this circuit, take heed – high voltages **CAN KILL!** NEVER touch any high-voltage part of the circuit with either fingers or uninsulated tools unless the power is OFF! While power is on, you should only touch any part of a circuit with an insulated test probe when required. Every time you switch off, adopt the following industrial safety procedure, known by the acronym 'SIDE', which spells out the following steps:

SWITCH OFF – Switch off the main PSU front panel rocker switch, and switch off at the mains outlet wall socket.
ISOLATE – Pull the mains lead out of the mains inlet socket at the back of the PSU.
DISCHARGE – Discharge the main line HT reservoir capacitor to zero volts (**NOT** with a screwdriver!).
EARTH – Earth the main line HT to chassis 0V with a leakage resistor to prevent any electrolytics recovering a charge from their own dielectric absorption.

In the design of the PSU 'discharging' and 'earthing' is automatically taken care of by R2 in the PSU circuit. Please note that it may take the resistor up to one minute to completely discharge the unloaded HT to 0V. To make doubly sure, you **MUST** test the main line HT with a multimeter set to high DC volts before touching any part of any circuit. This shall hereon be referred to as 'the SIDE procedure'. **DON'T CUT CORNERS!**

PSU Construction

More detailed instructions are provided in the leaflet (XV10L), the PCB is assembled with reference to Figure 2, the PCB legend Figure 2 and the Parts List.

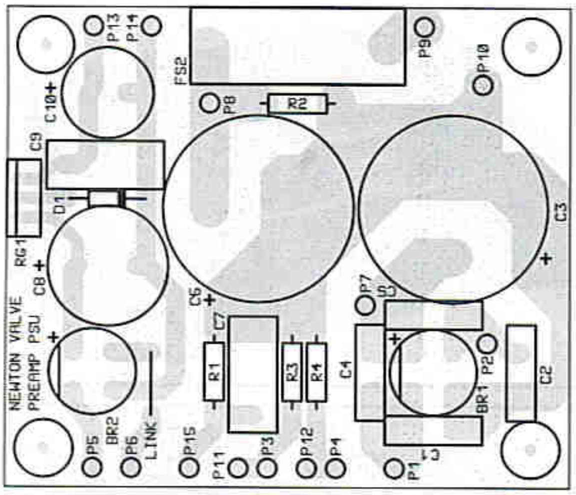
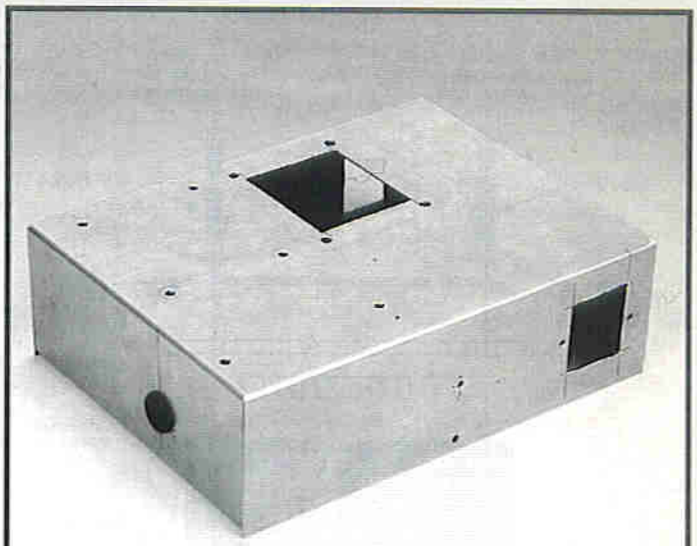


Figure 2. PSU PCB legend.



Drilled Chassis.

Regulator IC RG1 is a type having a plastic mounting tab instead of a metal one. This will make assembly into the chassis much easier as there is no need for a mica insulating kit. While the metal tab would be at earth potential if it were used, and not need an insulating kit anyway, for the reasons discussed earlier the DC heater supply must remain electrically isolated from the chassis. This is mentioned in case you were thinking of substituting RG1 with a different device.

Double-check the PCB for the quality of solder joints and correct orientation of components. Once the PCB is installed in the chassis it will be quite awkward to remove again to correct errors! The PCB includes a solder resist on the track side. After removing flux with a PCB cleaner, track side solder joints should be covered with a conformal coating to help the solder resist prevent creepage, or tracking, between points of high potential difference. Some areas are at the full HT line potential.

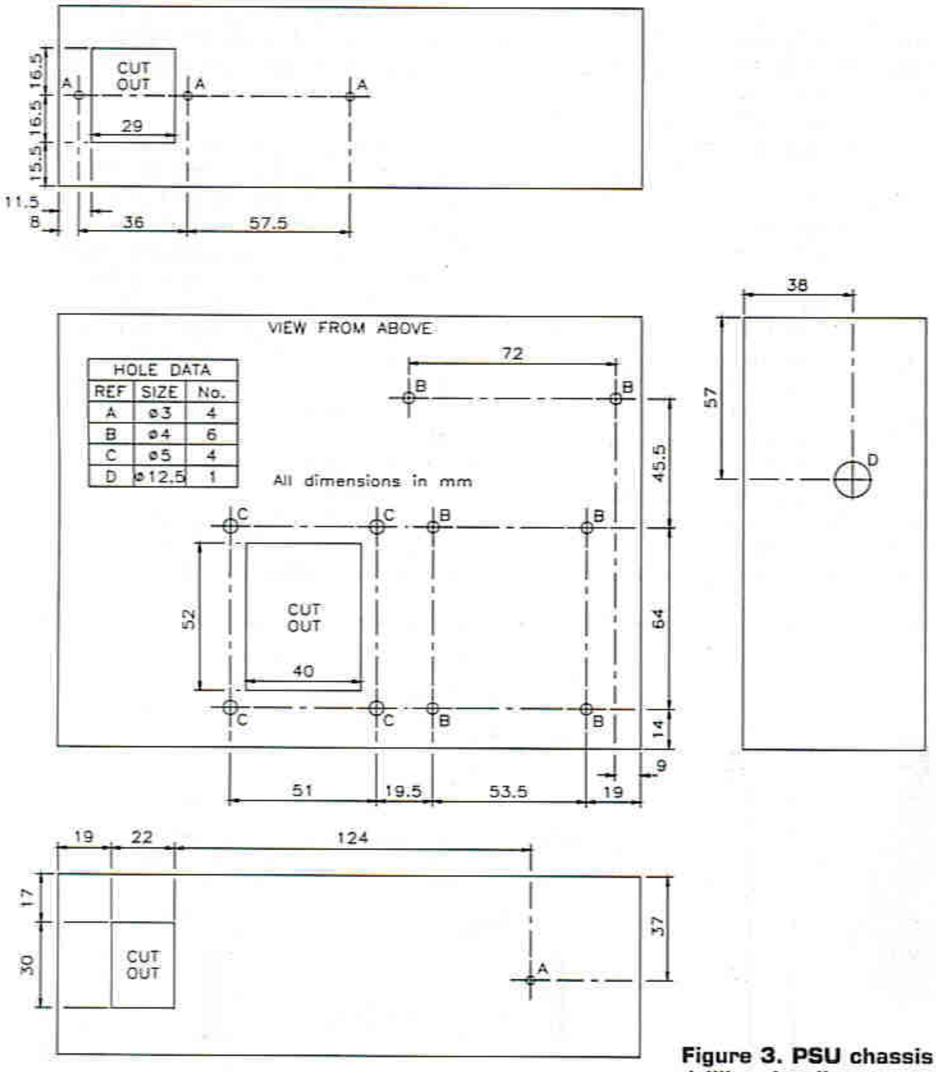


Figure 3. PSU chassis drilling details.

Preparing the Chassis

Cutting and drilling details are given in Figure 3. All holes are made in the main body of the 8 × 6in. aluminium chassis; the removable lid will become the bottom, not the top!

Assembling the Chassis

With all holes prepared, begin by mounting T1 with reference to Figure 4. To comply with Class 1 requirements for mains powered equipment, we must ensure that the top cover of T1 is satisfactorily earthed to the chassis metalwork on fitting. It is not sufficient to rely on a metal-to-metal contact. One bolt should have its fibre washer replaced with an M5 shakeproof washer. Also place the rectangular steel frame over the lower side of the former, carefully manoeuvring it over the solder tags, until it seats onto the core.

Supporting the chassis on its side with T1 *in situ* (don't let it move!), place three of the fibre washers, plain washers, shakeproof washers and nuts (supplied in a plastic bag with the transformer) only onto those bolts also having fibre washers at the top, and tighten lightly. For the bolt having the shakeproof washer at the top, replace its fibre and plain washers, then add the M5 solder-tag washer beneath the shakeproof washer and nut. This should be one of the two bolts near the centre of the chassis. Eventually an earth strap will connect this to the chassis; by having shakeproof washers at the top and bottom, this bolt will ensure that the top cover is electrically earthed.

This done, install the mains rocker switch by pressing it into its rectangular cut-out (all terminals orientated towards what will be the

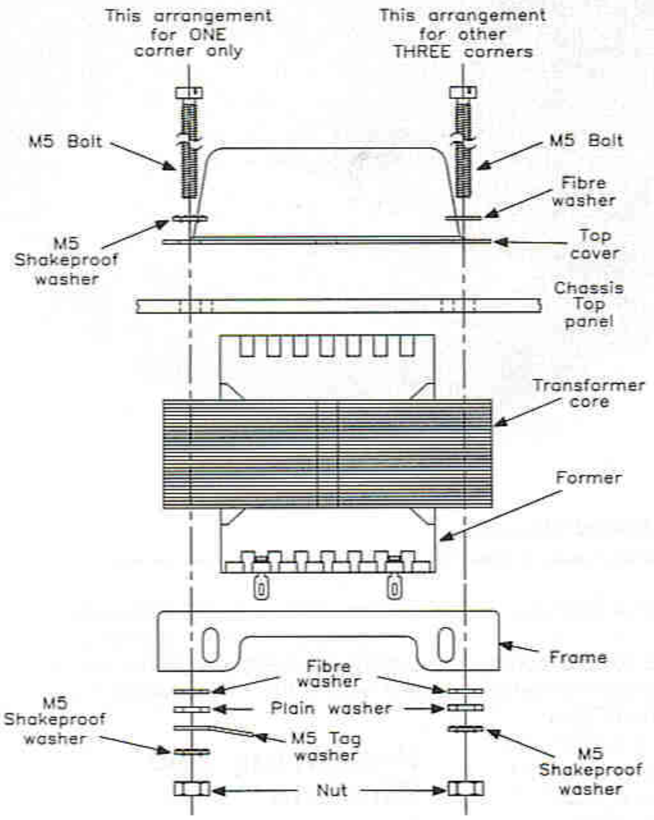
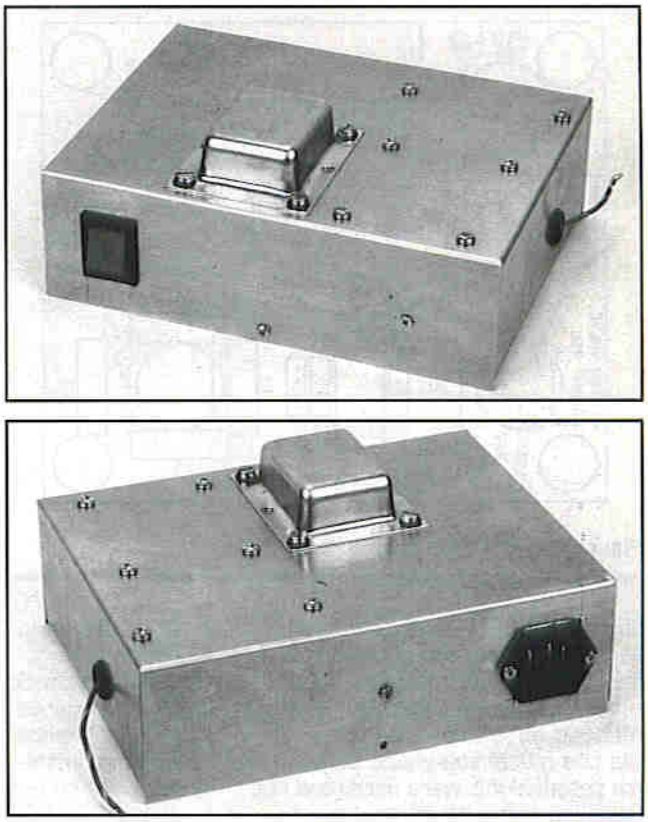


Figure 4. Mounting the mains transformer.



Front and rear view of the completed Newton Preamplifier PSU.

top of the chassis) then the fused Euro mains inlet socket at the rear (fuse tray towards what will be the bottom of the chassis). Secure in place with two M3 × 10mm bolts, shakeproof washers and nuts.

Mount the four M4 × 14mm threaded spacers to the inside of the chassis if not already in place, using the two M4 × 10mm screws through the top panel.

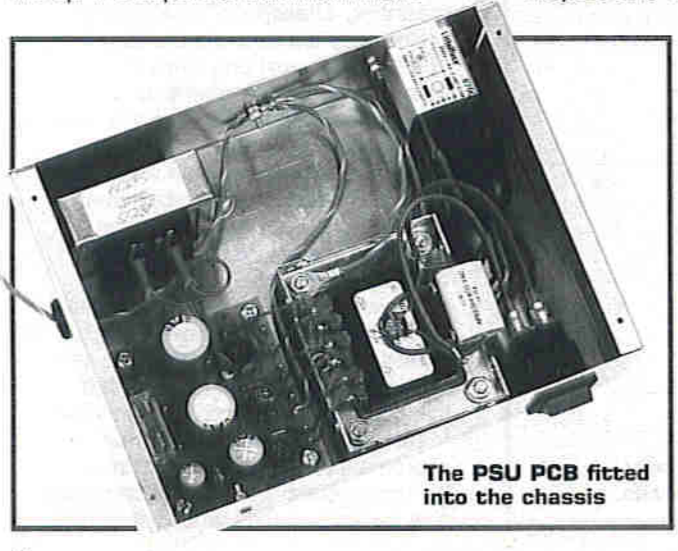
Mount the choke to the rear corner of the top panel using M4 × 10mm bolts, shakeproof washers and nuts as in Figure 5. The finished PCB can be installed onto its four mounting pillars. In so doing, carefully bend out the leads of RG1 so that it is flat against the inside of the front panel. Its fixing hole should be lined up with the M3 clearance hole drilled in the front panel; if this is not possible file out or re-drill the chassis hole until they do line up. If a separate aluminium front panel is fitted, this should be drilled at this position accurately. RG1 is retained with a countersunk M3 screw, shakeproof washer and nut; the separately fitted front panel should have a countersunk hole such that the screw head is flush with the surface. Thereafter it can be hidden with filler and paint or a stick-on front panel label. DO NOT over-tighten! The PCB is secured with four M4 × 6mm bolts to the pillars.

Mains Wiring

Complete the mains side wiring with reference to Figure 9a. Prepare a 23cm length of green/yellow power connection wire with a ¼in. push-on connector crimped on one stripped end (no insulating sleeve required), and push the connector onto the ¼in. earth terminal of SK1.

Prepare one blue and one brown 15cm length of power wire with insulated ¼in. push-on connectors at each end, and include the insulating boot for SK1. Prepare a further blue and brown pair, 12cm long, with insulated connectors at one end of each only.

Referring to Figure 9a, connect the Live and Neutral terminals of the Euro mains inlet socket SK1 with the lower (as you see them from the bottom of the chassis) Live and Neutral terminals of the rocker switch SW1 (not the central pair), using the brown and blue 15cm leads. Also push the green/yellow earth lead from the earth terminal of SK1 through the boot, and cover all connections of SK1 with the boot. The boot should be stretched over the rear end of the metal body of SK1, and may need persuading with a thin-bladed screwdriver or similar, and perhaps a little lubricant. (It may be a good idea to press the boot onto SK1



The PSU PCB fitted into the chassis

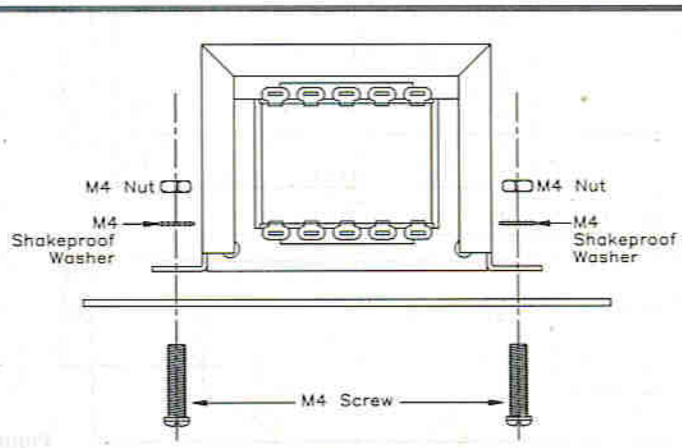


Figure 5. Mounting the choke on the chassis.

as soon as you receive the kit to 'train' it into the right shape before final assembly.) Likewise connect the brown and blue 12cm leads to the central terminals of SW1.

Transformer Primary Connections

The primaries of T1 are wired according to the country of use, that is for UK/European or USA/North American operation:

- For UK/European use, join the centre two primary tags on T1 with a single short length of power wire, as shown in Figure 6a.
- For USA/North American use, connect the primaries in parallel using two short lengths of power wire as in Figure 6b.

Simultaneously hardwire the yellow 220nF polypropylene capacitor C11, with the transient suppressor TS1, across the outer pair of primary tags, locating them as shown in Figure 9a (or Figure 9b). Both should have their leads sleeved with insulation stripped from power connection wire:

- For use in the UK/Europe, TS1 should be the 250V type.

For use in the USA/North America, TS1 should be the 130V type.

Strip and solder the loose ends of the 12cm leads from SW1 to the same outer mains primary solder tags of T1; trim lengths to suit.

Earth Wiring

Solder an M3 solder-tag washer to the loose end of the green/yellow wire from SK1. Prepare 18 and 6cm lengths of green/yellow power wire with M3 solder-tag washers at one end only. Prepare a 20cm length of green/yellow power wire with M3 solder-tag washers at both ends.

Connect all four wires to the common earthing point on the rear panel using an M3 × 10mm bolt and nut. Two shakeproof washers should be situated on either side of the stack of four solder tags, that is at the chassis surface and beneath the nut. The 'free' earthing strap is to connect the PSU and the preamplifier chassis together electrically via the

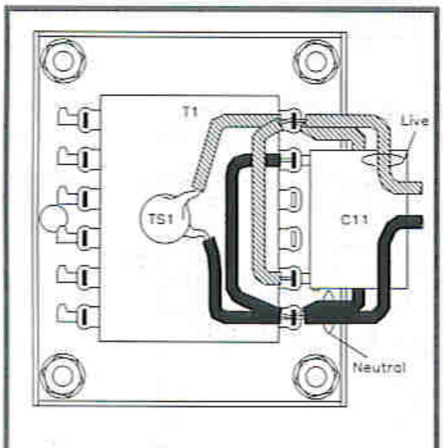


Figure 6b. Configuring for US/ North American mains standard.

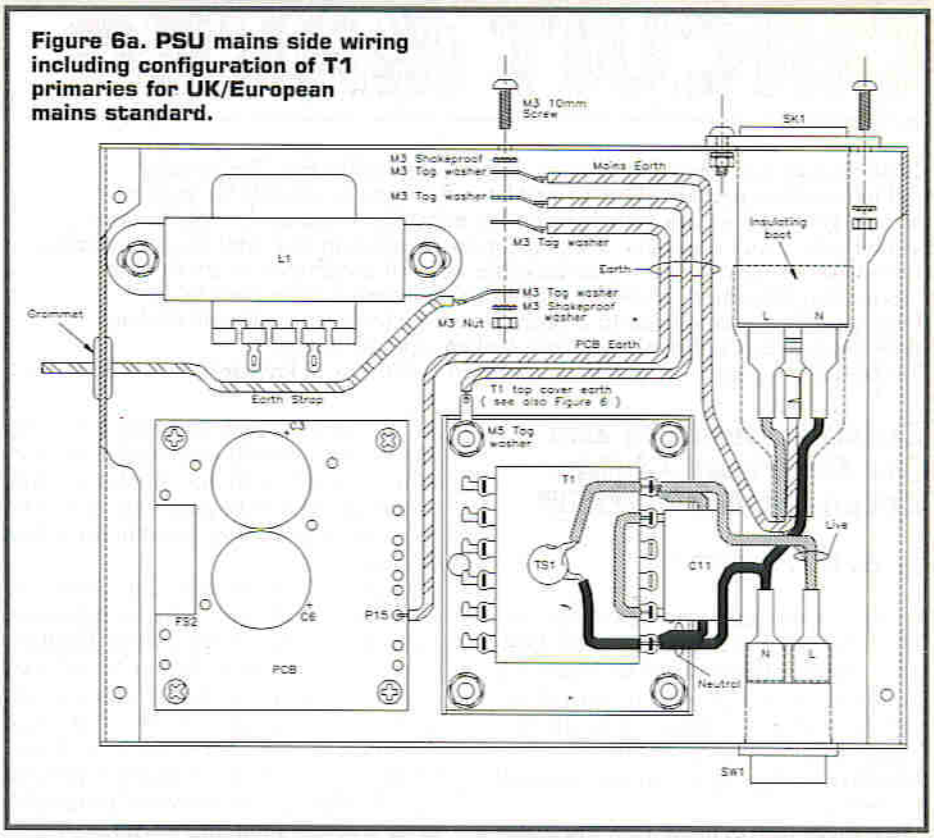


Figure 6a. PSU mains side wiring including configuration of T1 primaries for UK/European mains standard.

interconnecting grommet when they are joined, and is attached to each via dedicated fixings, using M3 × 10mm bolts, shakeproof washers and nuts at each tag washer.

Finally install the fuse F1 into the fuseholder tray of SK1 (the tray is released by squeezing the clips at either side), the value of which is according to the country of use:

- For UK/European use, fit the F500mA ceramic fuse.
- For USA/North American use, fit the F1A ceramic fuse.

Secondary Side Wiring

Referring to Figure 7, connect six lengths of brown, stranded hook-up wire to the secondary tags of T1 (approximately 4cm long). Cover each tag with a ½in. length of red, heat-resistant sleeving. Connect to the PCB as follows: the 15V pair to P5 & P6; 6·3V pair to P3 & P4; 250V pair to P1 & P2.

Connect the choke tags to P7 & P8 with brown hook-up wire, with heat-

Continued on page 71.

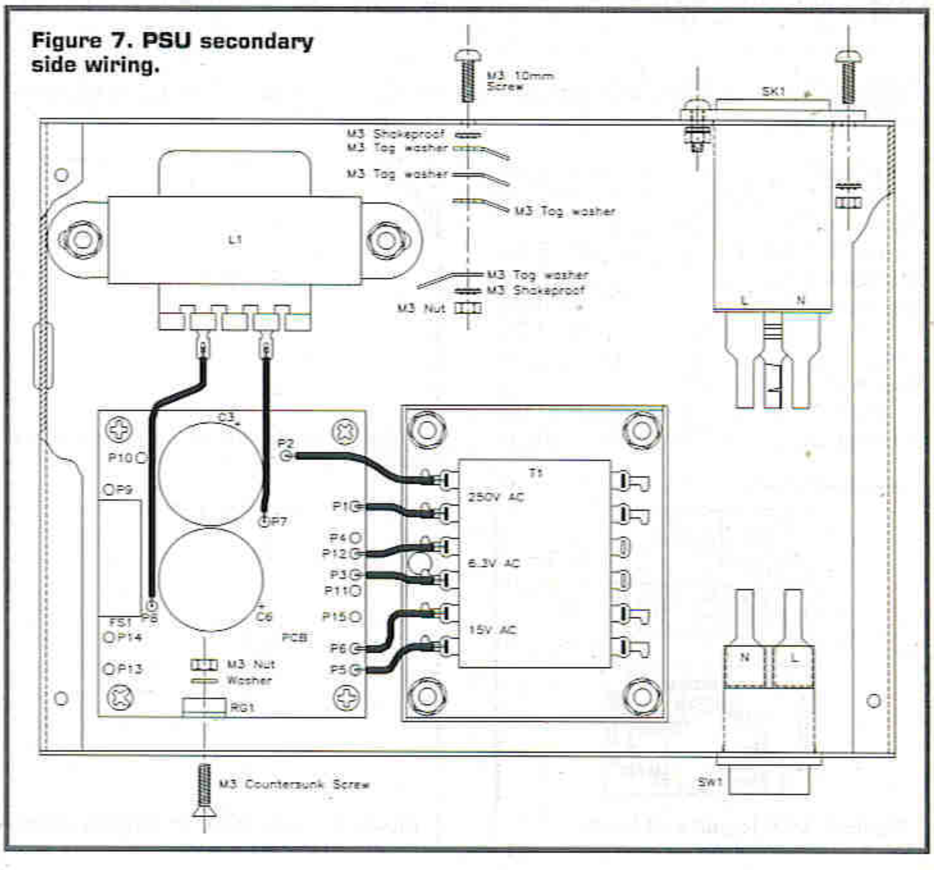


Figure 7. PSU secondary side wiring.

Circuit Maker

Circuit Maker is a forum for readers' circuits, ideas and tips. The circuits and information presented here must be considered as a basis for your own experimentation, no warranty is given for suitability in particular applications, reliability or circuit operation. Maplin cannot support, in any way, the information presented here. However, where possible, we will endeavour to check that information presented, is correct and that circuits will function as stated.
If you would like your ideas to be considered for inclusion in Circuit Maker, please mark your submission 'Circuit Maker' and send it to:
The Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

Enhancement to the Car Courtesy Light Extender Kit LP66W

by A. N. Piggott

For some time now I have been fitting self-flashing LEDs to the dashboards of cars owned by family and friends, in order to provide a visual deterrent to casual or opportunist thieves. Hopefully this will persuade the would-be thief that there is an alarm system fitted to the vehicle.

The basic idea is to connect the anode of the LED to a permanently live source, and the cathode to a connection which would only become live with the ignition on. With the ignition switched off, the LED would have the potential of 12V DC across it, and the current will drain through the car's electrical components, causing the LED to flash. Alternatively with the ignition switched on, the LED would have the same 12V DC at both leads and not operate.

When I first came across the Car Courtesy Light Extender, and in particular the ignition override part of it, I realised that it would be possible to combine this kit with the flashing LED, providing two useful gadgets in one. (The extra components are listed in the modified parts list.)

Figure 1 shows the Car Courtesy Extender circuit with a high-brightness, 5mm red flashing LED added (UK36P). The LED is actually driven by its own internal IC timer, which includes a constant current supply feed so that the device maintains constant brightness. Diode D3, a 1N4148, is added to prevent the LED being reversed when the ignition is on and the doors are opened.

As an additional safety feature the power for the LED comes from the lower switched (earth side) of the courtesy light bulb which means that, in the event of the LED wiring short circuiting, the current flow would be limited to the normal bulb operating current. As described in the original article, R2 in Figure 1 determines the maximum time delay (when the ignition is off) by charging C1, and the wattage of the courtesy lamp affects the time. Figure 2 shows the time delays given at various values of R2 for 5, 10, 15, and 20W lamps.

The diode and LED combination can be simply connected across pins P1 & P2 (see Figure 3). For the LED to be operational the ignition must be off, the doors closed and the courtesy light itself must be off after the delay. In practice the LED will flash dimly when the light delay circuit is operational with the ignition off, returning to full brightness as the courtesy light is extinguished. Figures 4 and 5 show the wiring arrangements for both negatively and positively switched courtesy lights.

I have now built and fitted several of these to various cars, so far with excellent results. However, when carrying out any form of electrical work on a vehicle, always make sure you disconnect the battery and *never* work inside the engine compartment while the engine is running!

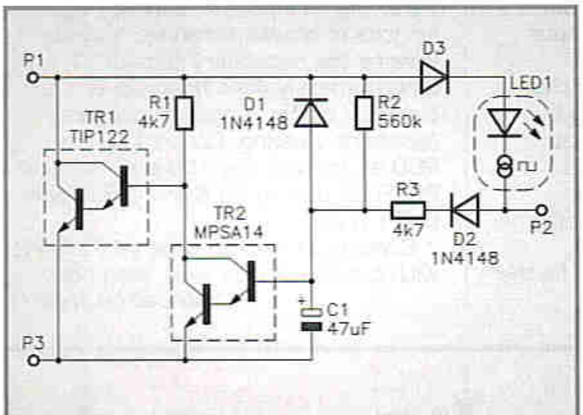


Figure 1. Circuit diagram with flashing LED added.

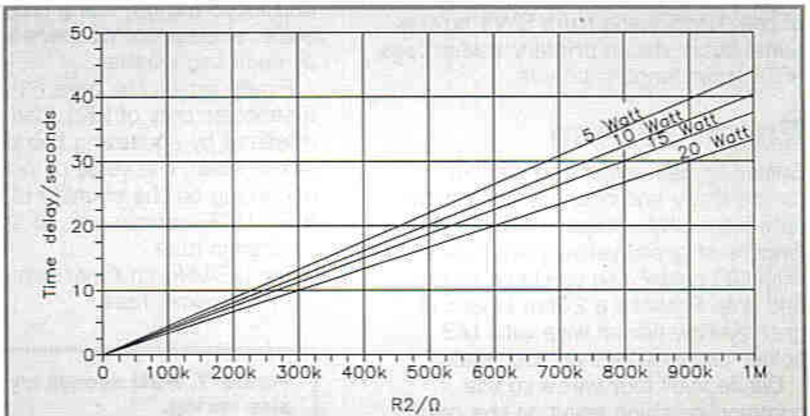


Figure 2. Graph of R2 against time delay for various wattage courtesy lamps.

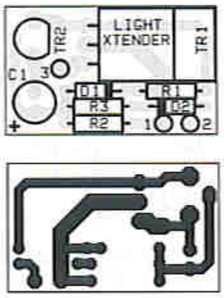


Figure 3. PCB legend and track.

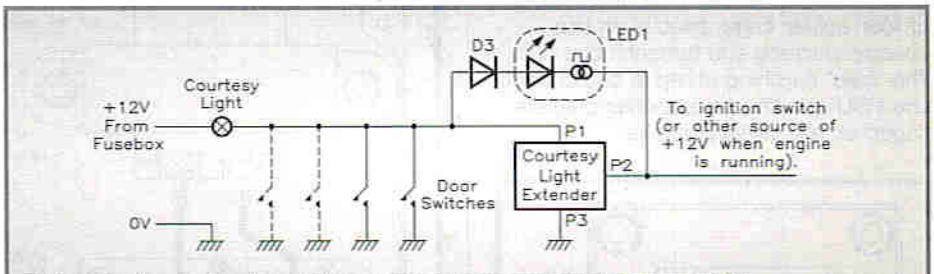


Figure 4. Connection for vehicles with negative switched courtesy light.

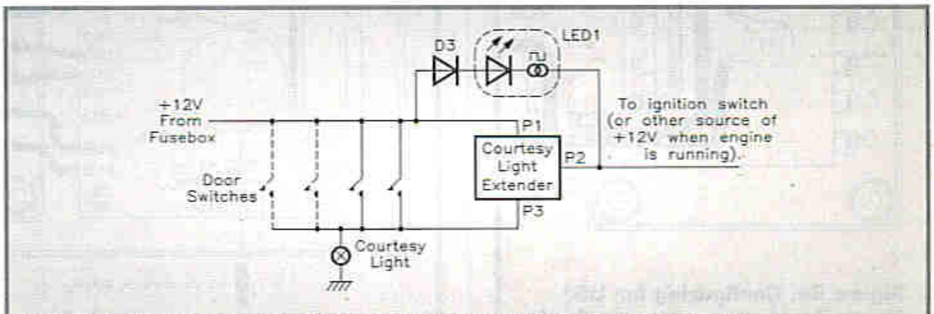


Figure 5. Connection for vehicles with positive switched courtesy light.

COURTESY LIGHT PARTS LIST

RESISTORS: All 0·6W 1% Metal Film			
R1,3	4k7	2	(M4K7)
R2	560k	1	(M560K)
CAPACITORS			
C1	47μF 16V Minelect	1	(YY37S)
SEMICONDUCTORS			
TR1	TIP122	1	(WQ73Q)
TR2	MPSA14	1	(QH60Q)
D1,2	1N4148	2	(QL80B)
MISCELLANEOUS			
P1,2,3	1mm PCB Pins	1 Pkt	(FL24B)
	PCB	1	(GE81C)
	Miniature Box and Base	1	(JX56L)
	Instruction Leaflet	1	(XK96E)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
D3	1N4148	1	(QL80B)
LED1	5mm Red Hi-Bright Flashing LED	1	(UK36P)
	Black Hook-Up Wire (10m)	1 Pk	(FA26D)
	Red Hook-Up Wire (10m)	1 Pk	(FA33L)

The above items, excluding Optional, are available as a kit.
Order As LP66W (Courtesy Light Extender Kit) Price £3.49

The following items are available separately.
Courtesy Light PCB **Order As GE81C 99p**
Miniature Box and Base **Order As JX56L 69p**

NEWTON STEREO VALVE PREAMPLIFIER PSU – *Continued from page 69.*

resistant sleeving over the choke solder tags. With this the PSU is complete.

Testing The PSU

With the chassis still upside down and the bottom cover off, plug a Euro mains lead into SK1, switch on at the mains socket and switch on the front panel rocker SW1. The red neon lamp should light and the transformer may be heard to hum slightly.

Set a multimeter to its highest (i.e., 500 to 1000V) AC voltage range, and with insulated probes check for 250V AC (approximately) at T1 secondary output pins P1, P2 on the PCB. Remove probes. Switch to 10V AC range or equivalent, and check heater supply output across pins P11 & P12, it should be 6·3V between both pins, and 3·15V between either and the common earth '0VE' P10 on the PCB.

Switch to a high DC volts range (500 to 1000V), and test the main line HT output against '0VE' (black probe to P10, red probe to P9). It should be approximately 350V DC. (In use the HT level is reduced, due to internal winding resistance in the T1 HT secondary, to approximately 300V.) Remove probes.

Switch off at the front panel. Stand by with the multimeter probes and recheck the HT level. It should be falling; this proves that the safety discharge resistor R2 is working. If you need to sort out a problem, carry out the complete SIDE procedure BEFORE TOUCHING ANYTHING! It will take nearly a minute for the HT to completely discharge, in the absence of any other load.

If all is well after the above tests, switch off at the mains socket and remove the mains lead. Apply both the Mains Warning and High Voltage Warning labels to the bottom cover, and temporarily fit it to the chassis with four of the self-tapping screws. ∎

NEWTON VALVE PREAMP PSU PARTS LIST

RESISTORS All 0·6W 1% Metal Film			
R1	100Ω	1	(M100R)
R2	470k	1	(M470K)
R3,4	150Ω	2	(M150R)
CAPACITORS			
C1,2,3,4	High Voltage Disc Ceramic 10nF 500V	4	(BX15R)
C5,6	Radial Electrolytic 47μF 50V	2	(JL18U)
C7,9	Mylar Film 220nF	2	(WW83E)
C8	Radial Electrolytic 1000μF 35V	1	(FF18U)
C10	Radial Electrolytic 470μF 35V	1	(FF16S)
C11	Polypropylene 220nF 1000V (Class X/Y)	1	(FA22Y)
SEMICONDUCTORS			
D1	BAX16	1	(QB29G)
RG1	L7812CP	1	(CR16S)
BR1,2	W04	2	(QL40T)
MISCELLANEOUS			
TS1	Transient Suppressor 250V AC	1	(HW13P)
TS1	Transient Suppressor 130V AC	1	(CP75S)
L1	10H 100mA Choke	1	(ST28F)
T1	115V/230V to 350V/15V/6·3V Transformer	1	(ST29G)
FS1	F500mA 20mm Ceramic Fuse	1 Pkt	(DA05F)
FS1	F1A 20mm Ceramic Fuse	1 Pkt	(DA06G)
FS2	F100mA 20mm Glass Fuse	1	(WR00A)
	PCB Fuseholder and Cover	1	(KU29G)
S1	Dual Red Neon Rocker Switch	1	(YR70M)
SK1	Fused Inlet/Filter	1	(KR99H)
	Cover For Fused Inlet/Filter	1	(JK67X)
	Aluminium Chassis AC86	1	(XB68Y)
	¼in. Push-on Receptacle	1 Pkt	(HF10L)
	¼in. Push-on Receptacle Covers	1 Pkt	(FE65V)
	9·5mm Grommet	1 Pkt	(JX63T)
	Mains Warning Label	1	(WH48C)
	HV Warning Label	1	(DM55K)
	6A Green/Yellow Wire	1m	(XR38R)
	6A Brown Wire	1m	(XR34M)
	6A Blue Wire	1m	(XR33L)
	1·4A Brown Wire (10m)	1 Pk	(BL02C)
	Red Heat-Resistant Sleeving	1m	(BL70M)
	Single Ended 1mm PCB Pin	1 Pkt	(FL24B)
	M3 × 10mm Steel Bolt	1 Pkt	(JY22Y)
	M3 × 10mm Countersunk Bolt	1 Pkt	(LR57M)
	M3 Steel Nut	1 Pkt	(JD61R)
	M3 Shakeproof Washer	1 Pkt	(BF44X)
	M4 Steel Nut	1 Pkt	(JD60Q)
	M4 × 10mm Steel Bolt	1 Pkt	(JY14Q)
	M4 × 6mm Steel Bolt	1 Pkt	(JY13P)
	M4 × 14mm Threaded Spacer	1 Pkt	(FG39N)
	M5 Solder Tag	1 Pkt	(LR62S)
	M3 Solder Tag	1 Pkt	(LR64U)
	M4 Shakeproof Washer	1 Pkt	(BF43W)
	PCB	1	(GH98G)
	Instruction Leaflet	1	(XV10L)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	Euro Outlet	As Req.	(HL42V)
	Insulating Cover for Euro Outlet	As Req.	(JK69A)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available as kits, which offers a saving over buying the parts separately.
Order As LT75S (Newton PSU Kit) Price £44.99 B4

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately, but are not shown in the 1995 Maplin Catalogue.
Newton PSU PCB **Order As GH98G Price £2.49**
10H 100mA Choke **Order As ST28F Price £5.99**
115/230V to 350V/15V/6·3V Transformer **Order As ST29G Price £19.99 A2**

REPAIRING RADIOS

Many a good transistor radio has had to be thrown into the rubbish bin after developing a fault. Unfortunately, servicing costs these days mean that it is not usually economical to have a radio repaired, particularly if it was not very expensive. However, with a little expertise and 'know-how' it is often quite easy to fix them and put an extra lease of life into an old radio. Sometimes it may only take a few minutes to effect a repair, other times it may take longer. But, either way, it will save some cash by saving the cost of the repair or a new radio, and it is worth having a go because there is nothing to lose. This month's article concludes with advice on practical fault-finding methods.

PART TWO BY IAN POOLE

Fault-Finding Methods

When fault-finding in a radio progresses beyond looking for the very simple faults it is necessary to adopt a logical and systematic approach. First of all the radio should be checked to ensure that power is getting through – obviously if there is some form of output from the speaker, power is present on the radio. Then, the audio amplifier should be checked, then the IF stages one by one and finally the RF stages and local oscillator. If this sort of logic is used then the faulty stage should soon be located.

Signal Tracing

The quickest way of tracing a fault is to inject a signal into various parts of the radio to determine which stages work. The ideal instrument to use is a signal generator. Obviously for testing audio circuits this should be capable of covering frequencies down to 250Hz or less. Then for testing the RF and IF stages of an AM radio it should be capable of generating signals between 100kHz and about 1·5MHz. On top of this it should be possible to amplitude modulate the RF signal with an audio tone so that the signal can be heard. Similarly for an FM radio, a generator, covering 10·7MHz as well as the FM bands is required, and it should be possible to apply frequency modulation. Unfortunately not everyone has access to all this equipment, and so it is necessary to improvise. Fortunately, this is not too difficult in most cases.

The first place to inject a signal is into the audio amplifier. The easiest, and hence best, place to try first is on the wiper of the volume control. A tone of about 250Hz and a few millivolts is best, and this should produce an audible signal at the output.

If a signal generator is not to hand a simple screwdriver can be used. If the metal shaft is held whilst it is touched onto the wiper connection then a click and some mains hum or other pick-up should be heard. But beware – this approach should not be used if the radio is connected to the mains, because some of the circuitry may be at mains or half mains potential!

If this test produces an output the fault lies in the RF or IF stages. If not then a signal can be injected onto the base of each of the audio transistors. When doing this with a signal generator check that it is AC coupled otherwise the DC resistance of the generator will disrupt the bias arrangements of the amplifier. If there is any doubt, or if it is DC coupled, a capacitor should be used between the generator and the circuit as shown in Figure 9. Obviously, as the signal is injected nearer to the output the level of the generator will have to be increased. This also means that the screwdriver method is less likely to work.

If the audio amplifier is found to work then a signal will have to be injected into the IF stages. For this the generator should be set to 465kHz or thereabouts, and it should be modulated with an audio tone. Again, if a generator is not to hand then a screwdriver can be touched on the various parts of the circuit.

The circuit should be tested progressing back stage by stage from the audio input. The first check should be performed on the 'RF' side of the detector diode, then on the output of the last stage, then its input and so forth along the IF amplifier.

Again, ensure that the output of this generator is AC coupled. If not, insert a capacitor in the output test lead to ensure the DC conditions of the circuit are not disturbed.

Next it is necessary to check the operation of the local oscillator. This is best done by using another working radio placed next to the faulty one so that its local oscillator signal can be picked up. Generally the local oscillator will run on the high side of the indicated frequency, i.e., indicated frequency plus the intermediate frequency. If the second receiver is tuned to approximately the correct frequency, and then the faulty one is tuned around, then it is easy to identify any signals picked up from the faulty one.

After this, any RF and mixer stages should be tested. Normally in an AM radio the oscillator, mixer and RF stage are all combined into one, so if the oscil-

An AM/FM modulated function generator, capable of five waveforms and a frequency range extending from 0·1Hz to 2MHz.

Figure 9. AC coupling a signal generator.

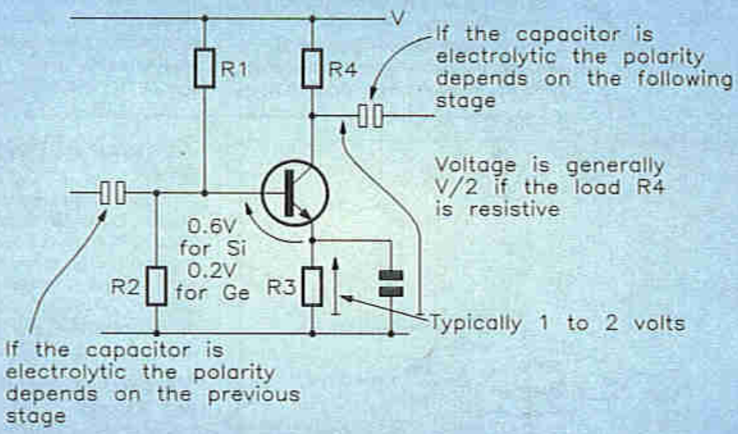


Figure 10. A basic transistor amplifier stage with bias resistors.

A typical shortwave receiver being repaired.

Using a second receiver to pick up the local oscillator frequency from the faulty receiver.

lator works the basic conditions for the stage must be correct and any problems with it are likely to be more minor.

Locating the Component

Having located the faulty stage in the radio the next step is to locate the offending component and replace it. In order to do this it is necessary to know where to probe and what readings should be expected.

The first step is to make some DC checks around the defective stage using a test meter. Often, but not always, this will lead to the defective component, as it is sometimes possible for a circuit to not operate correctly whilst still having the correct DC conditions.

Figure 10 shows the basis of a typical transistor stage. R1 and R2 provide the base bias voltage. R4 is the collector load and R3 provides a measure of DC negative feedback. This is needed to ensure the circuit operates correctly over a wide temperature range and a wide spread of circuit tolerances.

The first check is to ensure that the supply voltage is present for the particular stage in question. Having done this the collector, base and emitter connections can be probed.

If the collector load is a coil as in an IF amplifier then the voltage will be the same, or very nearly the same, as the supply voltage. However, if the load is resistive then the voltage measured here should be about half the supply.

The emitter voltage will generally be about a volt or two above ground. Finally, the base voltage should be about 0·6V higher than the emitter voltage if the transistor is silicon. However, if it is germanium then it will be about 0·2 or 0·3V.

If these conditions are not met then it could be for a number of reasons. For example, if the base junction of the transistor has blown then it is possible that no current would be flowing in the collector emitter circuit. This would mean that there would be no voltage across the emitter resistor and the collector would be at the same potential as the supply.

Another possibility could be that the collector and emitter are shorted internally. If this happens then the collector and emitter will obviously be at exactly the same potential. However, beware, very similar conditions occur if the transistor is turned hard on.

Although transistors are often the reason for a circuit failing they are by no means the only one. Resistors fail occasionally, especially if they dissipate a lot of heat. They are also quite easy to locate in most cases, as they will control the DC bias conditions, and if they fail the results will be very easy to detect with a multimeter.

More difficult to detect will be the effects of a failing capacitor. (In addition to this they can fail in a number of different ways. For example, electrolytic capacitors will often become leaky as they become old, especially if they are not used for a while.) This could drastically alter the bias conditions if it was used to couple one stage to the next or if it was used to bypass the emitter resistor.

Continued on page 79.

NEWS Report

High Speed LAN

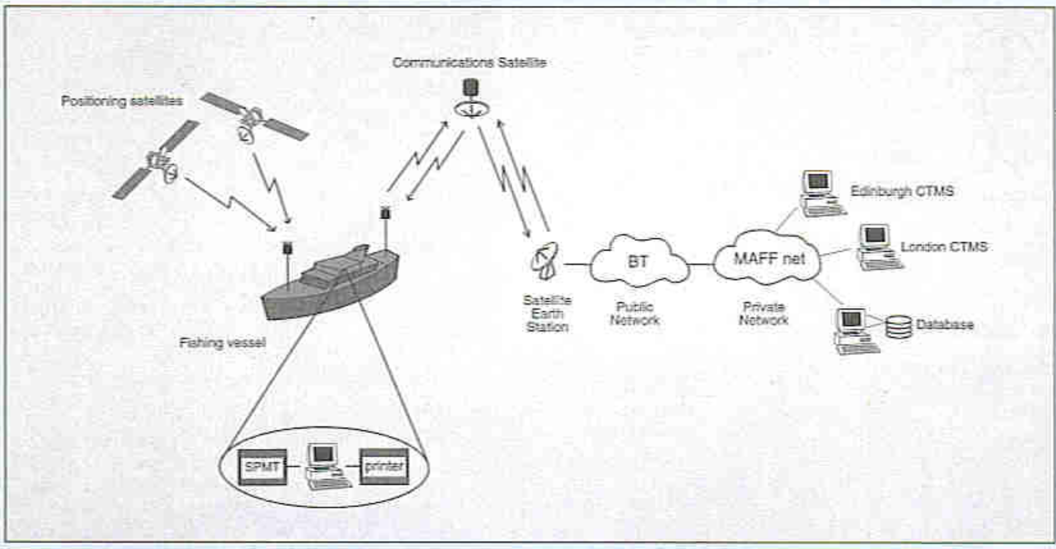
Two industry leaders, Texas Instruments and Compaq Computer Corporation, have joined together to develop a new networking architecture capable of high speeds and flexible enough to accommodate different protocols. This new technology, known as ThunderLAN, is designed to provide networking customers a clear path to 100 to 200M-bit/s networking from existing local area network (LAN) environments. This new architecture, which supports either of the high-speed Ethernet standards (100 Base-T or 100 VG-AnyLan) increases performance up to ten times over that of existing LAN implementations. Contact: Texas Instruments, Tel: (01234) 223511.

Radiation Hard ASICS

Actel Corporation and Loral Federal Systems, have announced an agreement to jointly develop the first radiation-hardened, non-volatile field-programmable gate arrays (FPGAs).

The new devices will give designers working on military/aerospace applications which require high radiation tolerance access to high-capacity, high-performance FPGAs for the first time.

Engineers will be able to easily replace large numbers of separate integrated circuits in their systems with just one Actel device. This will enable the production of systems that are smaller and lighter than was possible before. Contact: Actel Europe, Tel: (01256) 29209.



Fisheries Department Monitors Fishing Vessels by Satellite

Smith System Engineering has been appointed by the United Kingdom Fisheries Departments to act as prime contractor for a nine month trial of a satellite-based tracking system for monitoring the position of fishing vessels. The UK trial is one of a set of parallel trials being undertaken by EU member states, as required by Article 3 of the EC Fisheries Control Regulation, Council Regulation (EEC) 2847/93, which came into operation on 1 January 1994. The purpose of the trials is to evaluate the use of electronic tracking systems for monitoring the movements of fishing vessels.

The trial will become operational in October and involves some 20 volunteer fishing vessels which will be fitted with Global Positioning System receivers and Data Transmission systems enabling automatic data transfer to Central Tracking and Monitoring Stations in London and Edinburgh via satellite.

The Council of European Ministers is required to decide before 1 January 1996, to what extent, and when a continuous position monitoring system, either land or satellite-based, should be installed on the Community's fishing fleet. In reaching its decision the Council will take into consideration the results of the pilot projects being carried out by all the Member States. Contact: Smith System Engineering, Tel: (01483) 442000.

Alliance of Voice and Data

An industry wide communications specification, Digital Simultaneous Voice and Data (DSVD), has been developed to enable PC users to talk and share applications over a single telephone line using a V.34 modem. Contact: Intel, Tel: (01793) 696000.

Variable Gain Amplifiers for Video

The EL4451 and EL4452 are a new generation of cost conscious variable gain amplifiers, which include a high performance output amplifier, in a monolithic design. These wideband, two-quadrant multiplier/gain control amplifiers offer wide bandwidth and excellent linearity, and are designed for variable filters, faders, level controls, and automatic gain control circuits operating with a signal bandwidth of up to 70MHz. Contact: Elantec, Tel: (0171) 482 4596.

Boundary Scan Testing at System Level

A new 'Addressable Scan Port' device that permits the individual testing of as many as 1,021 boards installed in a system was announced by Texas Instruments at the 25th annual International Test Conference in Washington DC earlier this month. The Addressable Scan Port is the industry's first device to allow the application of IEEE 1149.1 boundary scan chip-and board-level test patterns throughout an entire system without re-formatting.

For system designers implementing in-system test and maintenance for improved system up-time and reliability, such as high-end computers and telecommunications equipment, TI's Addressable Scan Port offers a way to distribute IEEE 1149.1 test access across a backplane without additional logic. Contact: Texas Instruments, Tel: (01234) 223511.

Research Collaboration Benefits the Nation

Government funded research should be a national asset, exploited by both civil and defence sectors, said Professor Sir David Davies last month in his Inaugural Address as President of the Institution of Electrical Engineers (IEE).

Sir David, who is Chief Scientific Adviser, Ministry of Defence, was addressing an audience of over 500 senior engineers, industrialists, academics and civil servants at the IEE headquarters in London.

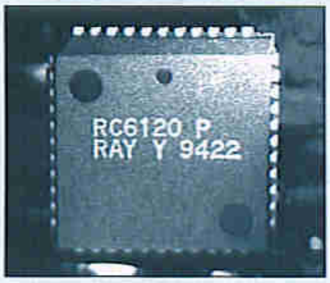
"The traditional view that defence research creates advanced technology which may produce spin-off for civil use is one-sided", said the IEE President.

"The growth of technology in the civil area is likely to influence defence thinking dramatically and lead to an improved defence capability at lower cost."

Sir David welcomed the recent restructuring of the UK Research Councils and the setting up of the Technology Foresight Programme, in which the MoD is playing a significant part. He also welcomed the establishment of Dual Use Technology Centres by the Defence Research Agency (DRA).

Sir David ended his IEE Presidential Address with a look at the UK Foresight Programme which will, for the first time, enable Government and industry to plan their research programmes against a background of views from a broadly based range of sources.

"This will strengthen the development of generic technologies and aid collaboration. It will also enhance the growing appreciation in defence that many of their technologies overlap strongly with the civil market and that defence has at least as much to gain from civil spin-in as the civil market does from defence spin-off." Contact: IEE, Tel: (0171) 240 1871.



Advanced Chroma Subcarrier Lock

The RC6120 is a highly integrated chroma subcarrier regenerator for NTSC or PAL signal decoding, which is able to function with either a burst or CW subcarrier input; locked to the subcarrier or free-running. The wide burst-gate generator enables the phase comparator function during the back porch interval.

The single chip design incorporates burst phase detector, burst gate generator, burst amplitude detector, voltage references, two sample/hold amplifiers, loop lock detectors and sampling pulse generator and steering logic. It adapts to incorrect burst amplitude and position, providing rapid signal locking and a long time constant to enable noise averaging.

A lock detector measures the subcarrier phase error and indicates the phase-lock status of the loop. This output can also be used to control the speed (bandwidth) of the loop filter. Contact: Microelectronics Technology, Tel: (01844) 278781.

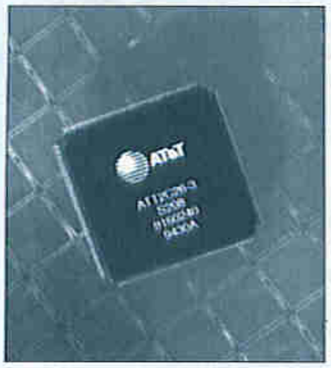
Improved Vocals

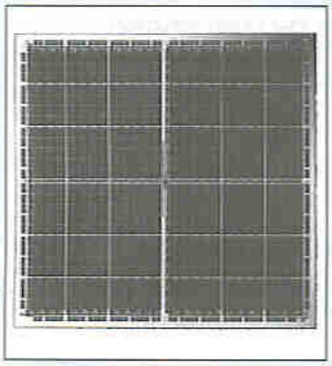
The CIC Voice Recognition System III can convert speech into electrical signals by using a microphone and a special interface board that codes the signals, so that they may be understood by the voice recognition program.

All other software applications on the PC continue to run as normal while the Voice Recognition III System runs in the background. Prices start from £580+VAT. Contact: CIC Computers, Tel: (0181) 813 8217.

Apple Profits Up

Net profits at Apple shot up in the fourth quarter to a record US$114·7m, from US$2·7m in the year-earlier period. Apple say this is due to sales of computers containing its new PowerPC chip. Contact: Apple, Tel: (0800) 127 753.





AT&T Announce 26,000 Gate FPGA

AT&T Microelectronics has announced the 26,000-gate ATT2C26 FPGA, claimed to be the industry's largest monolithic device. Like the recently introduced ATT2C15, the 2C26 is based on a half-micron, three level metal CMOS process.

Both the 2C15 and the 2C26 deliver clock rates of up to 150MHz, and meet the PCI bus specification with a pin-to-pin, clock-to-out delay of less than 11ns. Using PREP benchmarks as a reference, the 2C26 delivers an average capacity of 104 instances and an average benchmark speed of 50MHz. Contact: AT&T Microelectronics, Tel: (+44) 734 324 299.

Clear Future for UK in Electronics

The headlines over the past month say it all. Massive investments by NEC, Motorola and GEC. A high chance of a huge fabrication plant from AMD, and a possible one from Mitsubishi. People have doubted the UK's future in Electronics – particularly in fabrication. Today, the answer is obvious.

- The giant Samsung Group of South Korea is to spend £450m on building a factory complex in Cleveland, in the north-east England, to produce electronic goods ranging from semiconductors and PCs to microwave ovens. Around 3,000 jobs will be created. Contact: Samsung, Tel: (0181) 391 0168.
- GEC Plessy Semiconductors is to invest US$160m in an expansion of its Roborough wafer-fabrication plant. Output will be quadrupled by the new 200mm wafer investment. Contact: GEC Plessy Semiconductors, Tel: (01752) 693000.
- NEC has officially announced an investment of US$800m in a new plant at Livingston. The new site will cover 36 hectares and include 25,000 square metres of clean room. The main products will be 16 and 64M-bit DRAM followed by ASICs and microprocessor. Contact: NEC, Tel: (0181) 993 8111.

BT Price Deals Beat Mercury

Residential customers can get a better price deal from BT than they would from competitor Mercury Communications, according to an independent review published last month.

The report confirms that overall BT beats Mercury for typical residential customers.

Coopers & Lybrand, management consultants, evaluated the analysis and verified the conclusion of the report and are satisfied with its accuracy.

Comparing the best pricing and discount packages of both companies where call charges total at least £60 in a quarter, it shows that overall bills can be between 1·3% and 2·6% lower with BT.

BT customers would be better off by £1·56 per quarter if they spend between £60 and £80 a quarter on phone calls, and about £2·45 per quarter if call charges were between £80 and £100 per quarter. Contact: BT, Tel: (0171) 356 5369.

Pneumatic Cassette Receiver Offers Low-Cost Test Fixturing

Peak has added a pneumatically operated low-profile cassette receiver to its range of fixtures designed to interface printed-circuit boards with automatic test systems.

The new unit is based on Peak's cassette concept, which uses a series of cassettes which plug into a base unit. This approach offers flexibility and cost savings to customers who test a variety of different boards by eliminating the need to purchase a different fixture for each board. Contact: Peak Test Services, Tel: (0191) 387 1923.

Approved Modem under £100

Electronic Frontier has announced a new range of BABT approved modems starting at under £100, cheaper than many of the non-approved modems on sale. The 14.4 Frontier XL Internal modem, complete with card, Winfax Lite, Dosfax Lite and Comit for both Windows and DOS will retail for £99+VAT. Contact: Electronic Frontier, Tel: (01734) 810600.

Carrera Offer Internet Ready Notebooks

Carrera Technology announced the most fully featured notebook PCs yet available. The new machines offer users a unique Internet-ready capability with multimedia options for maximum flexibility.

Carrera's new range of notebooks are upgradable to Intel's 486 DX4/100 processors and incorporate local bus disk and video architecture for Windows and graphics performance. Through its relationship with 'easynet', the UK's newest Internet provider, Carrera will be bundling access software and a US Robotics Worldport PCMCIA modem for plug and play Internet or fax capability.

Each machine is shipped with a Trackpoint, a removable hard drive, a PCMCIA Type III slot and on-board sound as standard. All systems are fully upgradable and can be supplied with up to 32Mb of RAM and 600Mb of hard disk space. A TFT Screen, second battery and docking station are among the other options available. Prices for the notebooks start at £999. Contact: Carrera, Tel: (0171) 8300 486.

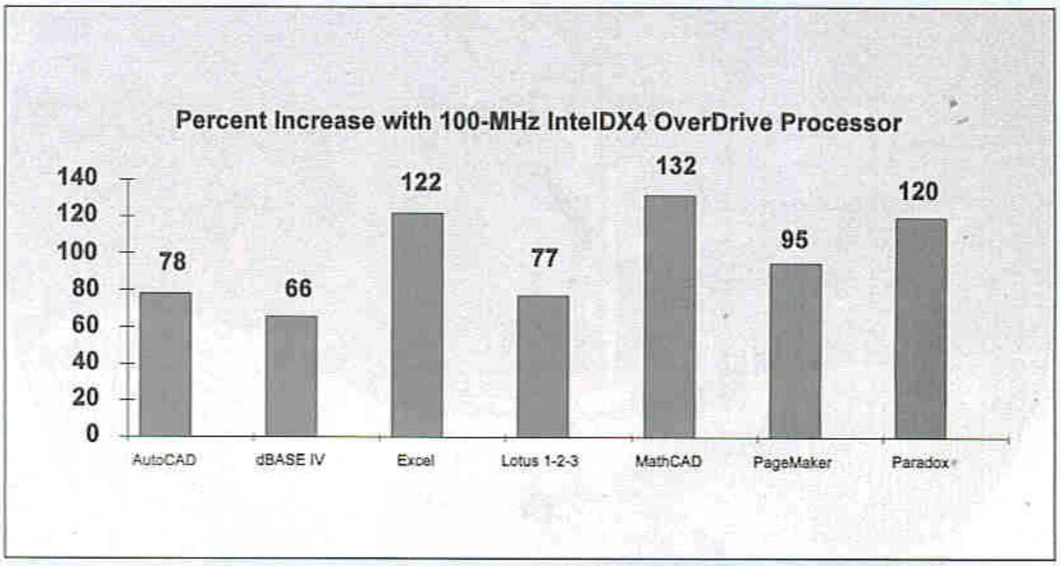
Aggressive Pricing for Scanners

Logitech, has slashed the prices of its range of hand-held and desktop scanners by as much as 25%. All models include Caere's Optical Character Recognition (OCR) software which allows users to recognise and convert text from an image format to a text form so that it can be used directly, just like text entered from the keyboard. In addition, Logitech's range of scanners support the TWAIN protocol for direct image support within Windows software applications. Contact: Logitech, Tel: (01344) 894300.

New Colour Screen

NEC has launched the first 24cm analogue LCD display. The natural colour screen has a standard RGB input, so it can be used to replace existing Cathode Ray Tubes (CRT).

Sophisticated control circuitry claims a number of other benefits including low power consumption (11W), infinite colours as opposed to 4,096 for traditional digital displays and brightness levels. Traditional LCDs have digital control circuits so that each pixel has a finite number of brightness levels. Contact: NEC, Tel: (0181) 993 8111.



Intel Overdrive Processor

The Intel DX4™ OverDrive™ processor is Intel's fastest member of the OverDrive processor family. The new CPU upgrade features 'speed tripling' technology and is available in both 75 and 100MHz versions. Intel has also reduced the prices of the current IntelDX2™ and IntelSX2™ OverDrive processors by up to 40%.

The new IntelDX4™ OverDrive™ processor is designed to upgrade Intel486 SX™ and DX CPU-based systems. An Intel486 SX CPU-based system currently running at 33MHz with an iCOMP index rating of 136, for example would operate at 100MHz internally and have an iCOMP index of 435 after being upgraded with the IntelDX4™ OverDrive™ processor. The iCOMP index is a relative performance rating for Intel's family of microprocessors, based on eight technical performance categories.

An upgraded 25MHz version of the same system would run at 75MHz internally and have an iCOMP index rating of 319. This translates to an overall performance boost of about 100% for all PC applications.

The IntelDX4™ OverDrive™ processor operates internally at 3·3V yet is compatible with 5V systems via a built-in voltage regulator. It includes an integrated floating point unit and incorporates a larger 16K on-chip cache, double that of the IntelSX2™ and IntelDX2™ OverDrive™ processors. Contact: Intel Corporation, Tel: (01793) 696000.

Text by Bob Kirsch
and Dennis Butcher

VHF Crossed Dipole aerial

A very important part of any radio communication system is the aerial and, although here are many different types, the easiest to use for weather satellite work on the VHF band is a crossed dipole aerial. Since such an aerial has a horizontally polarised *omnidirectional* polar pattern it means that, once in place, it is not necessary to align the aerial to the satellites passing overhead.

A highly recommended accessory to boost the received signal, is the VHF/UHF preamp as covered in *Electronics* Issue 81. The VHF/UHF preamp is easily fitted, and of course can be used with the MAPSAT2 Receiver, or any other type of receiver that covers the VHF/UHF spectrum. The preamp should be mounted on the mast itself.

The assembled VHF aerial.

KIT AVAILABLE (LM00A) PRICE £16.99 B2

3 PROJECT RATING

Construction

All the parts for the construction of the VHF crossed dipole aerial are provided in the kit, with the exception of a wooden broom handle for the support pole. This item should be available from most hardware stores. The broom handle, if not already varnished or painted, should receive such treatment before the construction of the aerial begins.

Prepare the squared end of the broom handle according to the details shown, (see Figure 1). Weather-proofed as described above and set aside until later. Carefully drill all holes in the plastic box, referring to Figure 2. It is important to ensure the correct positioning of each of the four holes in the box, which must be in the exact centre, flush with the 'floor' of the box to ensure the four aerial elements will be properly positioned at right-angles to each other. The rods MUST be a tight fit in the holes, as the box will later be filled with a liquid resin potting compound.

There are two types of coaxial cable provided in the kit. The longer length (usually brown) has an impedance of 75Ω and the shorter length (usually black) 50Ω, cut to size. Prepare the ends with reference to Figure 3.

The remaining length of 75Ω cable forms the main aerial feeder, one end of which should be prepared in a similar manner to the ends of the loops shown in Figure 3. Join the three lengths of coax together, referring to Figure 4.

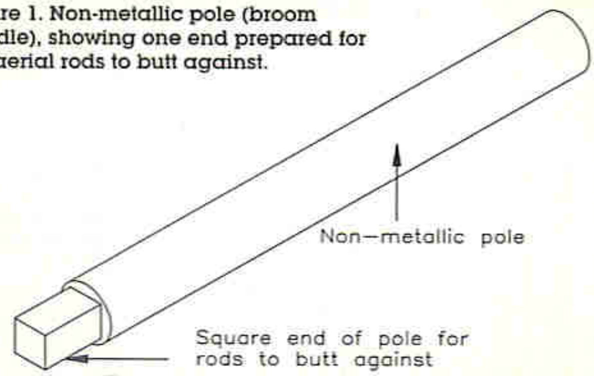
Ensure that there are no stray strands of the braided screen, which could come into contact with any of the centre conductors, causing short circuits. If necessary remove problem strands with side cutters. Drill a small pilot hole in the centre of the prepared end of the broom handle, and attach the plastic box to this using a suitable wood-screw (see Figure 5), then rotate the pole until the prepared flats are facing, and parallel with, the sides of the box. Make sure that the broom handle is vertical in relation to the base of the aerial's box.

Arrange for yourself a large, clear working area with plenty of space to move around in, and place the above assembly upside down, with the support pole vertical and the box at the bottom. Place on a flat surface (a level floor is ideal).

Plug both ends of each of the four aluminium rods using the eight 3/8in. blanking plugs supplied. Each rod has a small hole drilled near one end for attaching a solder tag. Insert *this* end of the rod into the box, and rotate if necessary to ensure that the small hole faces uppermost. The rod should be a reasonably tight fit in the box. Repeat the procedure for all rods, positioning them with reference to Figures 5 and 6. Note that they should butt against the squared end of the support pole, but *must not* touch each other!

Attach and position the four solder tags as shown in Figure 6, using the self-tapping screws provided. Now solder the ends of the previously prepared cables carefully to the tags (the sequence is indicated in Figures 4 and 6), making sure that each lettered termination correctly goes to the correspondingly lettered solder tag. Carefully check these terminations and make sure that the rods are not touching each other. Use an ohmmeter or continuity tester to check for continuity right through from the

Figure 1. Non-metallic pole (broom handle), showing one end prepared for the aerial rods to butt against.



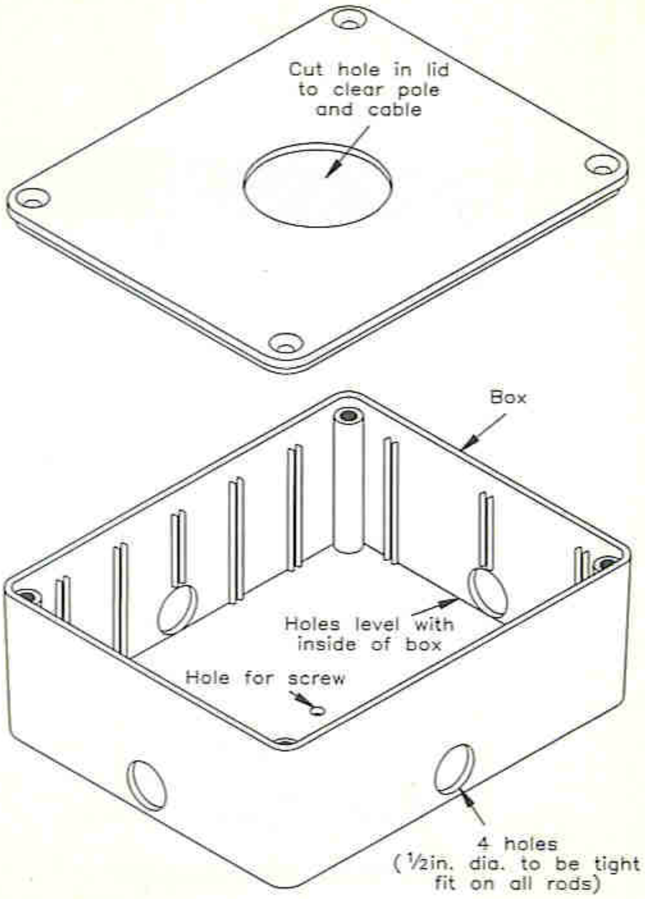
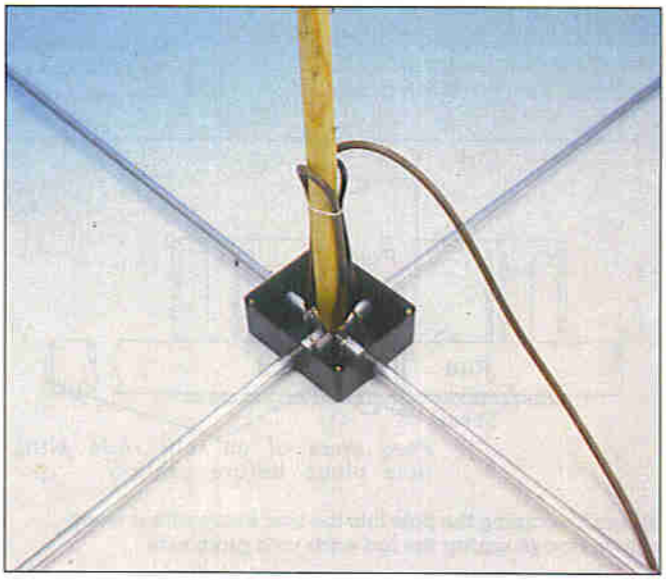
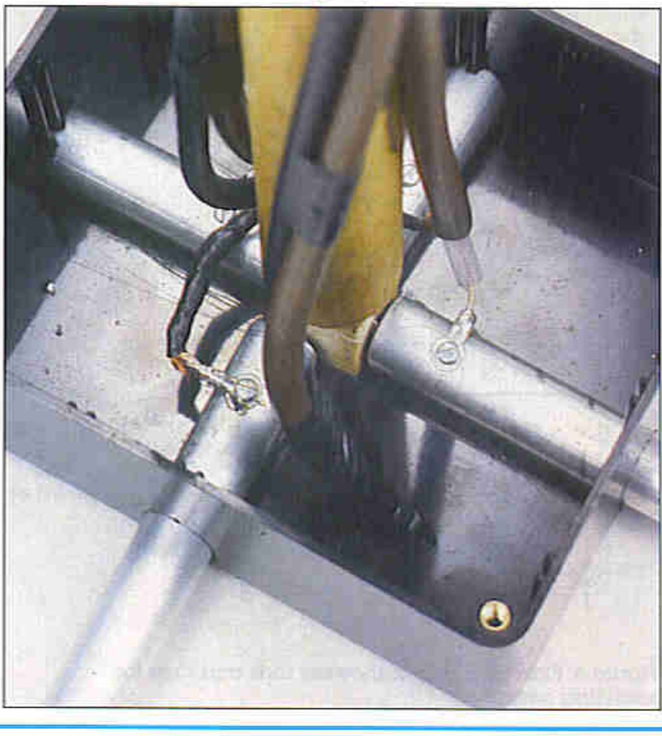


Figure 2. The aerial box drilling details.



Inside the box showing the pole, rods and coax in position before using the potting compound.



coaxial feeder to the actual aerial elements, and that there are no short circuits between screen and conductor along the way. Ensure that all solder joints are solid. It will be impossible to correct any mistakes or put right any problems once the assembly is sealed in resin.

Secure the cable as shown in Figure 7, making sure the taped junction between the feeder coax and the free end of the 50Ω loop will be below the level of the resin when the box is filled.

Mix the resin, referring to the instructions supplied with the pack, and slowly fill the box to the level as shown in Figure 7. Check all terminations are covered. Be careful that no resin enters the box lid securing holes. Check all rods are positioned correctly, supporting them where necessary while the resin hardens. Leave the assembly for approximately 12 hours for the resin curing process to be completed.

When the compound has hardened, attach the box lid and secure the cables to the broom handle or support as shown in Figure 7. The aerial is now ready for installation.

Standard 75Ω low-loss coax is used as a down lead. Use standard Belling Lee type VHF aerial connectors (not supplied) to join the feeder to the down lead, but protect these from the weather if the aerial is to be used in an exposed position; self-amalgamating tape is ideal for this purpose. At the other end of the cable, fit the coax plug supplied; this plugs into SKT4 on the back of the MAPSAT2 Receiver unit. The aerial should be installed as high as possible, and as far away from any other aerials, buildings or large metal objects as is practical. E

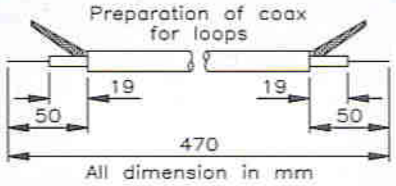


Figure 3. Preparation of the coax for the loops.

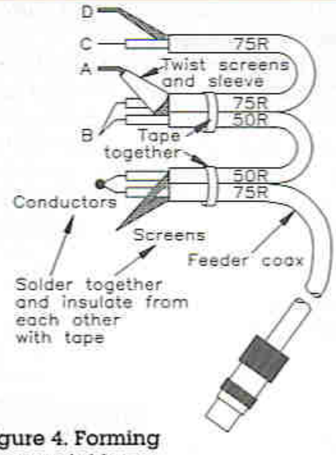


Figure 4. Forming the coaxial loops.

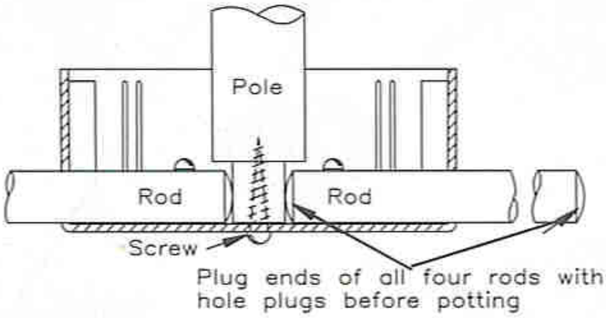
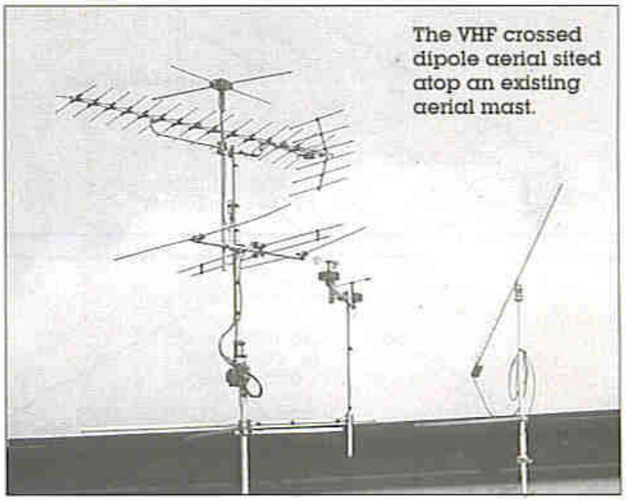


Figure 5. Locating the pole into the box, fixing with a wood-screw, and plugging the rod ends with grommets.



The VHF crossed dipole aerial sited atop an existing aerial mast.

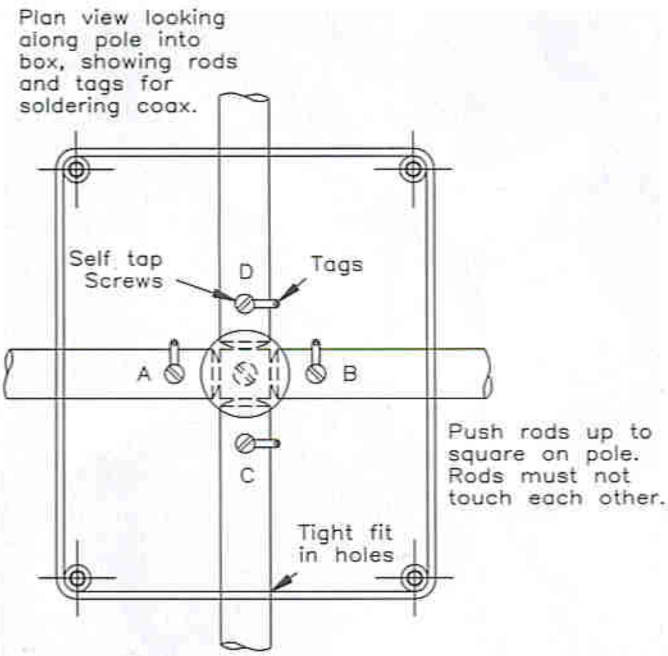


Figure 6. Plan view of box showing rods and tags for soldering coax.

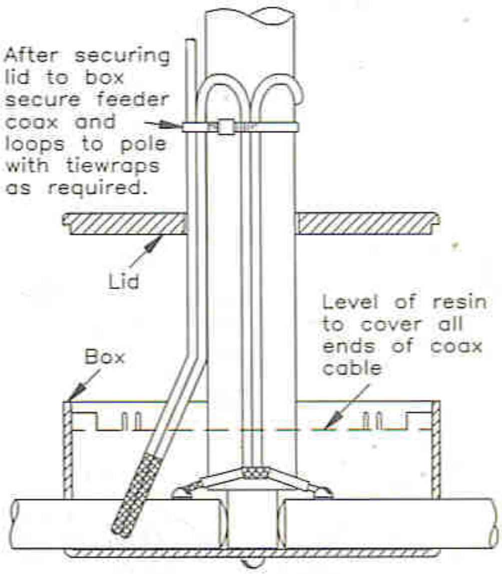


Figure 7. VHF aerial final assembly.

AERIAL PARTS LIST

MISCELLANEOUS

	ABS Box MB3	1	(LH22Y)
	Aerial Rod	4	(YM58N)
	⅜in. Hole Plug	1 Pkt	(JX61R)
PL4	High Quality Coax Plug	1	(FD85G)
	No.2 × $^3/_{16}$in. Self-Tapper	1 Pkt	(BF64U)
	8BA Solder Tag	1 Pkt	(LR02C)
	75Ω Brown Low-Loss Coax	5m	(XR29G)
	50Ω Black Low C Cable	1m	(XR19V)
	Potting Compound 250g	1	(FT19V)
	Tie-Wrap 203/2·5	5	(BF93B)
	Black PVC Tape 20m	1	(FM84F)
	Instruction Leaflet	1	(XT94C)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

Wooden Pole 1in. dia.	1
Wood Screw	1

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LM00A (MAPSAT Aerial Kit) Price £16.99 B2

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

REPAIRING RADIOS – *Continued from page 73.*

Capacitors can also fail open circuit. If this happened to one which was used to couple one stage to the next then it would have the effect of completely stopping the signal. Again if one was used for an emitter bypass capacitor then it would cause the gain of the circuit to be reduced.

Component Testing

Having located and removed the suspect component it is worth checking it out of circuit to confirm whether it is faulty or not.

Resistors are obviously easy to check as all test meters have resistance ranges. Usually if resistors fail they will become open circuit, although they can, on occasions, change their value if they have been subjected to heat.

Capacitor testing is a little more difficult, unless one owns one of the newer digital meters with a capacitance range. If one does not then all is not lost. Fortunately it is possible to give capacitors over a few microfarads a very rudimentary sort of test. If the suspect capacitor is placed across the multimeter on a high ohms range then the meter needle will deflect for a short while as the capacitor charges up. For very large value capacitors it may take even a few minutes for this to happen, whereas for small values the deflections will be very short. It is also found that for electrolytics there will be a small amount of leakage with the leads connected in one sense. This is perfectly normal provided that it is not too high. Unfortunately it is not possible to set down exact values for these measurements as they will vary from one meter to another.

It is possible to give transistors a fairly good test using a standard meter on its ohms range. By looking at the construction of a transistor it can be seen that it can be represented as two back to back diodes as in Figure 11. This can be tested quite simply by connecting one of the meter leads to the base, and the other to the collector and then the emitter. Then the leads should be reversed and the test repeated. It should be found that the meter should conduct with the leads connected in one sense but not the other. A final test should be made by checking the resistance between the collector and the emitter. This should appear as an open circuit for most modern transistors, although some germanium transistors and particularly power transistors will have a slightly lower resistance.

An LCD capacitance meter, providing measurements over a very wide range.

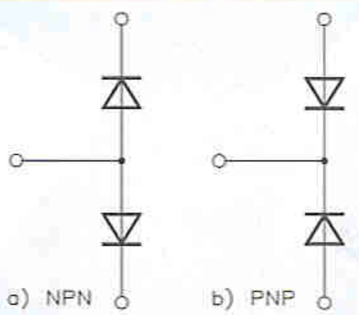


Figure 11. Representation of a transistor for testing with a test meter.

When transistors have a collector emitter failure it is usually a virtual short circuit. Typically the resistance will be just an ohm or two. However, there is still likely to be a diode junction between the base and the shorted collector emitter circuit.

Sometimes it is not feasible to check out a component. In this case the only real course left open is to substitute a good known component. This is obviously not the best way of fault-finding because it can lead to components being swapped several times with the resultant possibility of damage to the board.

Safety

Whatever repairs are performed on a radio, great care should be taken if it is mains driven. Even with the power switch turned off, many radios still have mains power in them. A favourite trick is to allow the mains transformer to remain connected all the time, and only switch the low voltage side of the circuit. Occasionally very old radios may use a dropper resistor to reduce any voltages from the 240V mains. This was particularly common in valve televisions, and it meant that the circuit was connected directly to the mains. Sometimes the chassis could be live! So the message is that if the radio is mains powered be very careful.

Final Thoughts

Many good radios which are discarded could have been repaired quite easily with a little work. Even if they have seen better years they could still be mended and used in the workshop to provide many further years of service. Often they only need a few minutes' attention. Sometimes they will obviously need more, but it can still give a great sense of achievement to fix a radio which had been destined for the rubbish heap.

@Internet

A new column for *Electronics – The Maplin Magazine:* to whet our readers' appetites for the Information Superhighway we give you news and views about the Internet.

One of the hardest things to learn when you first start on the Internet is that there's no one application which does everything for you. There may be in the future, but that's just a very shady *may be*, because the Internet itself is still developing at a fantastic rate of knots, and all developers within the Internet have their own ideas about the way forward.

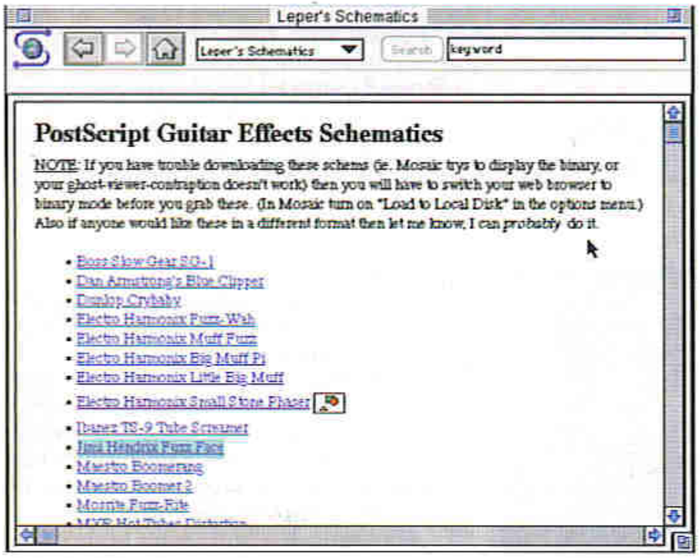
Still, that's great, because it means that we; the *users* of the Internet will always have something new to be playing (oops, I mean working) with. What *is* definite though, is that you need a range of tools, utilities and programs to do the job. Over the coming months we'll be describing all the utilities and what they're for. The first is TCP/IP.

TCP/IP stands for Transmission Control Protocol/Internet Protocol. It's effectively a defined procedure of communications between computers on the Internet – a language which all computers follow. In effect, to get onto the Internet, your computer has to follow the protocol too. Actually, there are other protocols (notably Unix to Unix CoPy, or UUCP) used on the Internet, but these are largely irrelevant to you logging on as a client. TCP/IP is the important one. It's this which splits up all the data flowing around the Internet into small packets of bits, and encodes each packet with the addresses of both its source and destination. Think of TCP/IP as an automatic envelope marker which marks a sequence of letters you're sending with the postcode of the person you're writing to, along with your postcode and the order in which it's sent. Now, if any of the letters get lost, it can always come back to you for resending. Once all the envelopes (OK, packets) are received at the other computer, they can all be joined together in sequence to rebuild the original file. Neat, huh?

TCP/IP utilities are available for *all* major computer platforms: PC, Mac, Atari ST, Amiga and Unix. You'll need a version for your computer. It's invisible to you as a user, but it needs to be there to let you get on the Internet.

An interesting development likely to become available early this year is an upgrading of FirstClass to support TCP/IP. FirstClass is a client/server mail system used by over 600 bulletin boards worldwide to provide a graphical front-end to their services. This means that anyone with a bog-standard Internet connection can access any of those bulletin boards which have a real-time link to the Internet. Thus, you can dial-up your usual Internet provider using your usual connection utilities, and from there jump to any connected FirstClass boards by running FirstClass Client – just as you jump to World Wide Web, say, using your favourite Web browser. We'll keep you posted on this, because FirstClass is a cracker of a system as it stands. The ability to jump worldwide will be a cool feature.

Rumours abound too, that the next version of Microsoft Windows will have integral TCP/IP support. The new version is scheduled for release about the middle of 1995, a fact which is reflected in its proposed name – Windows 95 – previously codenamed either Windows 4 (the current version is 3.1, after all) or more cryptically Chicago. When you think about it Microsoft would be grossly negligent if TCP/IP support was missed out. Yes, you can get TCP/IP utilities from third-parties along with third-party programs, but a solution which is integral to the operating system on a PC could be infinitely more suitable.



Site Survey
– the month's destination

Each month we take a quick look at an Internet destination which tickles our fancy. If you have any you think we should check-out, drop us an e-mail at **Site_Survey@maplin.demon.co.uk** – we can't guarantee a personal reply to every e-mail, but you never know – you may see your name in print.

This month we look after music freaks. Located on the World Wide Web (**http://www.oulu.fi/music.html**) is the Virtual Music Library, where you can access a multitude of musical information on the Internet. From your World Wide Web browser, hit the hyperlink to *musical instruments, programs and gadgets*, for example, to get a list of circuit diagrams (well, OK they're called *schematics*) of guitar effects pedals and gizmos. Hit the hyperlink you want and your requested circuit is downloaded to your computer. Also on the library is information on literally scores of artists and groups around the world. It's a nice site and if you're a modern music lover will take up literally hours of your time.

DID YOU MISS THESE PROJECTS?

The Maplin 'Get-You-Working' Service is available on all of these projects unless otherwise indicated.

These descriptions are necessarily short. Please ensure that you know exactly what the kit is and what it comprises before ordering, by checking the appropriate issue of *Electronics* referred to in the list. The referenced back-numbers of *Electronics* can be obtained, subject to availability, at £2.10 per copy.
Carriage Codes – Add: A: £1.55, B: £2.20, C: £2.80, D: £3.30, E: £3.90, F: £4.45, G: £5.35, H: £6.00.

To order Project Kits or back-numbers of *Electronics*, 'phone Credit Card Sales on (01702) 554161. Alternatively, send off the Order Coupon in this issue or visit your local Maplin store.

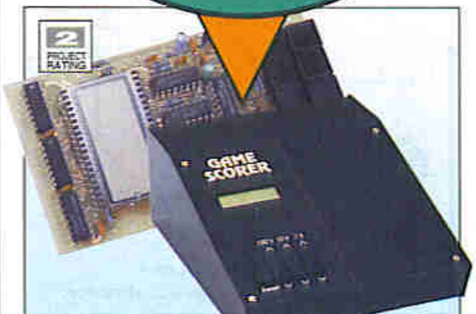
Maplin: The Positive Force In Electronics

All items subject to availability. Prices include VAT.

CHRISTMAS TREE LIGHT SEQUENCER

Give your Christmas tree an extra sparkle this year! When coupled to one or more sets of lights, this unit produces various interesting lighting sequences and fade patterns. The unit has three output channels each with a maximum output power of 400W, making it ideal for disco light sequencing, attention-grabbing shop window displays or an extremely bright Christmas tree! (Case not included in kit.)

Order as: LT69A, **£39.99**. Details in *Electronics* No. 84, December 1994 (XA84F).



GAME SCORER

The ideal companion for games of all kinds that require a score to be kept. Points can be added or subtracted in units, tens or hundreds and cleared to zero at the press of a single button. (Case not included in kit.)

Order as: LT68Y, **£24.99**. Details in *Electronics* No. 84, December 1994 (XA84F).

IN-CAR AMP PSU

Especially designed to enable the 400W Mono/Stereo Amplifier (VF40T) featured in November's *Electronics* to be used for in-car audio. Also suitable for other in-car systems requiring a ±35V, 300W, unregulated supply generated from the car's 12V supply.

Order as: VF38R, **£66.99** H0. Details in *Electronics* No. 84, December 1994 (XA84F).

DAY/NIGHT THERMOSTAT

Many heating controllers offer only a single fixed temperature setting and On or Off timing. This ingenious, compact thermostat also comprises a timer allowing different temperature settings for day or night, to be automatically selected. Requires only a simple 9 to 12V AC supply.

Order as: VF36P, **£49.99**. Details in *Electronics* No. 84, December 1994 (XA84F).

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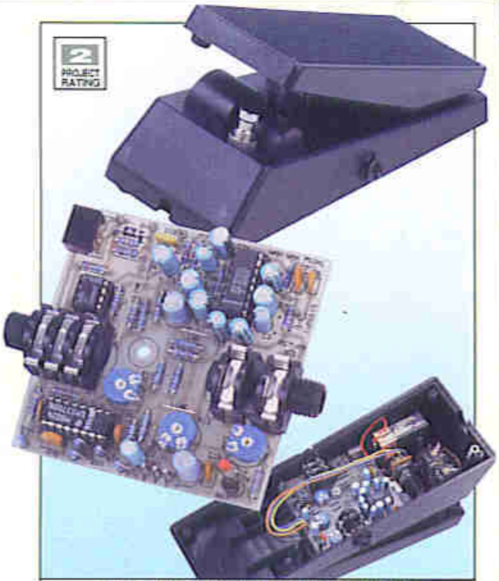
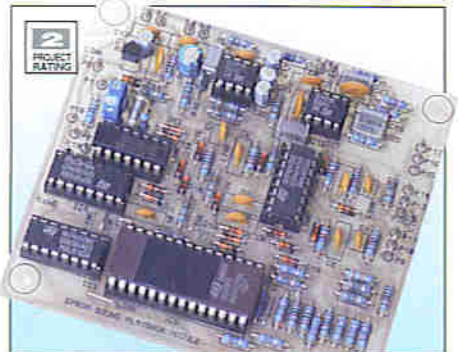


PSYCHEDELIC WAH WAH PEDAL

Recapture the classic sound of the '70s with this superb '90s technology Wah Wah Pedal. The kit includes a ready-made foot pedal and is ideal for electric guitars and other musical instruments.
Order as: LT43W, **£34.99** B3. Details in *Electronics* No. 82, October 1994 (XA82D).

2 METRE FM RECEIVER

An inexpensive 2 Metre frequency modulation (FM) receiver. Ideal for the newcomer just starting out, or for the dedicated enthusiast who wants to monitor a local frequency whilst keeping more sophisticated equipment free. (Case not included in kit)
Order as: CP21X, **£31.95**. Details in *Electronics* No. 83, November 1994 (XA83E).

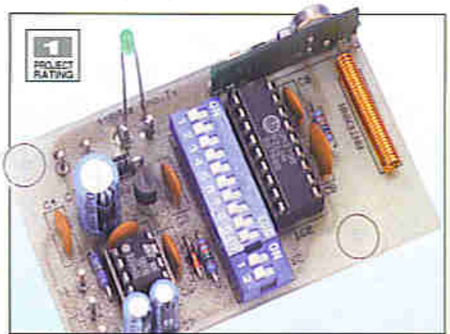


STEAM WHISTLE/2-TONE DIESEL HORN

A must for serious model train enthusiasts! Three separate trigger inputs allow either or both sounds to be played. This kit really does include everything – even the whistle and horn sounds are supplied on EPROM!
Order as: LT61R, **£14.99**. Details in *Electronics* No. 83, November 1994 (XA83E).

INDUCTANCE/CAPACITANCE METER ADAPTOR

Add inductance and capacitance ranges to your basic digital multimeter. This clever unit produces a DC voltage proportional to the inductance or capacitance under test, which can be measured by your existing meter. (Case not included in kit.)
Order as: RU38R, **£39.95**. Details in *Electronics* No. 82, October 1994 (XA82D).



418MHz ENCODED FM TRANSMITTER

A DTI approved transmitter which can be encoded with one of over 4,000 different codes. The transmitter can be triggered by a closing switch contact, which can be simply a push-button, or a negative going pulsed output from other equipment, e.g., the Telephone Bell Repeater kit, LT67X. Applications include remote control, wireless security systems, paging, help buttons, and much more.
Order as: LT87U, **£26.99**. Details in *Electronics* No.83, November 1994 (XA83E).

418MHz ENCODED FM RECEIVER

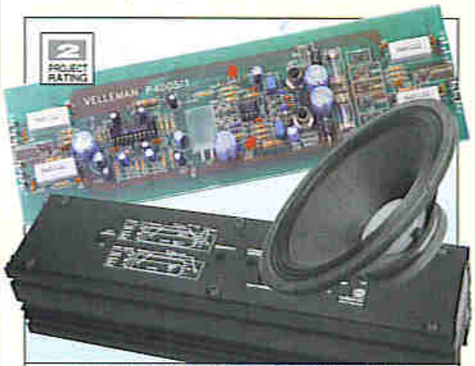
A DTI approved receiver for use with the 418MHz Encoded FM Transmitter. The receiver will only respond to a transmitter set with the same code.
When a correctly coded signal is detected by the receiver, an LED lights and a piezo sounder operates. Fitting a relay (not supplied) in place of the piezo sounder allows the receiver to operate other electrical equipment for remote control applications. (Case not included in kit.)
Order as: LT88V, **£39.99**. Details in *Electronics* No. 83, November 1994 (XA83E).

LOUDSPEAKER PROTECTOR

Help protect your valuable high-power loudspeakers from being damaged by DC voltages produced by a faulty amplifier. This unit constantly monitors the input to the speaker and 'disconnects' it if a DC voltage is detected.
Order as: VF44X, **£9.49**. Details in *Electronics* No. 82, October 1994 (XA82D).

INTELLIGENT CAR INTERIOR LIGHT CONTROLLER

Add the convenience of this 'intelligent' device to your car. It not only keeps the interior light on for 30 seconds after the door is shut, but also turns it off if the ignition is switched on before the 30 seconds elapse. Plus, it turns off the interior light after ten minutes if a door is accidentally left open, avoiding draining the battery. (Case not included in kit.)
Order as: LT65V, **£9.99**. Details in *Electronics* No. 82, October 1994 (XA82D).



400W MONO/STEREO AMPLIFIER

A compact and robust amplifier with a low harmonic distortion of only 0.003% at 1kHz. It can be configured as either a stereo amplifier producing 100W rms per channel into 4Ω speakers, or as a bridged mono amplifier producing 200W rms into a single 4Ω speaker. Total music output is 400W. Power supply voltage is ±30 to ±35V DC for 4Ω speakers or mono, and ±40 to ±45V DC for 8Ω speakers. (Speaker not included in kit.)
Order as: VF40T, **£59.99** H10. Details in *Electronics* No. 83, November 1994 (XA83E).

TELEPHONE BELL REPEATER

Requiring no direct connection to the telephone system, this unit picks up the ringing sound and repeats it elsewhere via a remotely wired piezo sounder. Alternatively the repeater can be connected to the 418MHz Encoded FM Transmitter and Receiver, LT87U and LT88V, to produce a 'wireless' telephone pager. (Box not included in kit.)
Order as: LT67X, **£10.99**. Details in *Electronics* No. 83, November 1994 (XA83E).

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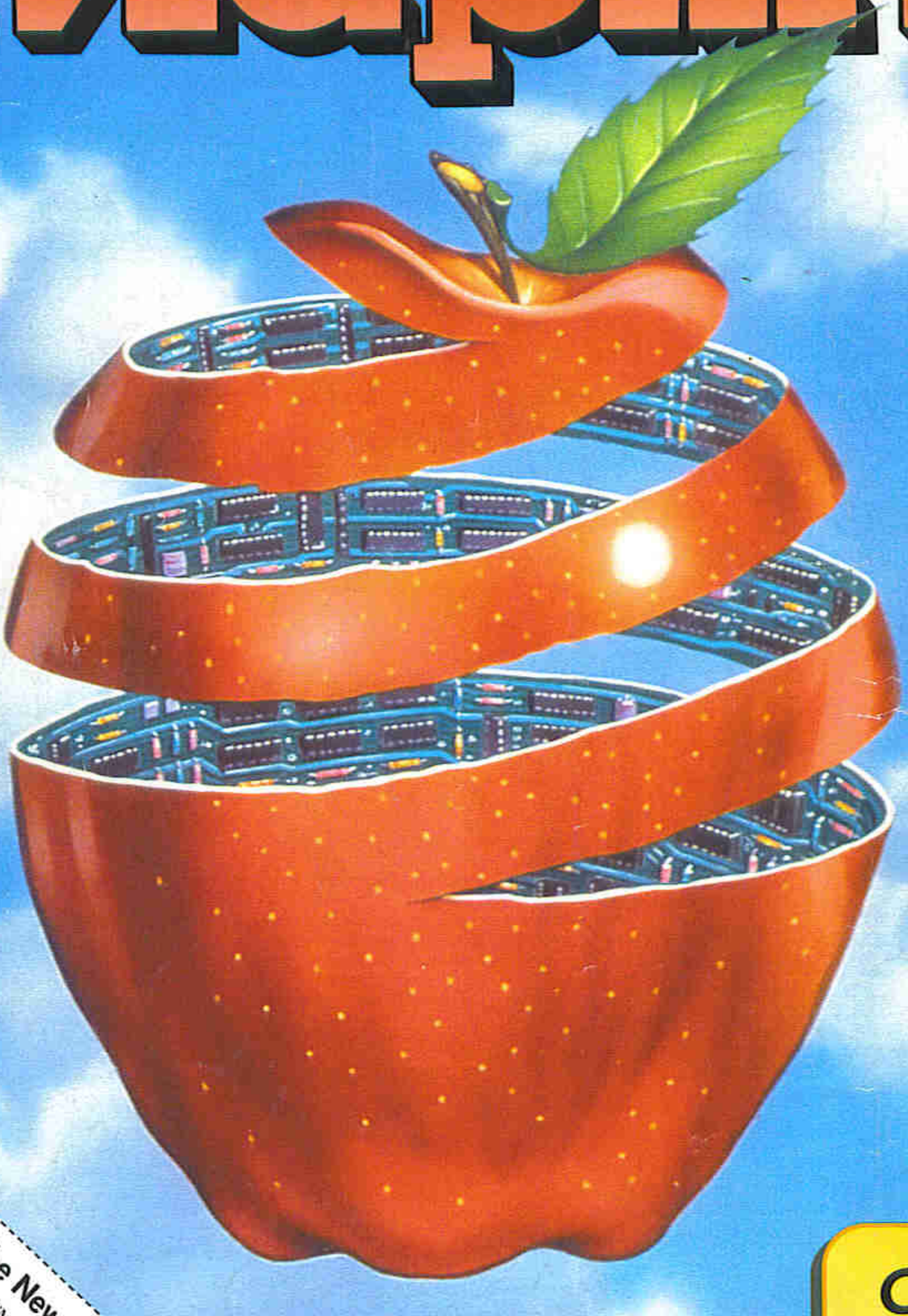

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