BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

No 41

DEC '90-JAN '91 · £1.45

ELECTRONICS
The Maplin Magazine

D·I·G·E·S·T FREE inside!

SPECIAL FEATURE:
Single Chip Microcontrollers

How to build a **Novelty CHRISTMAS TREE STAR** · **NICAM IR Remote Control Handset** · **MOSFET Amplifier** · **COMPUGUARD** · **WIN Ferry Tickets Across the Channel** · Data File **SSM2016 Differential Amplifier** · Read all about **TAPE RECORDING** · **DIGITAL LOGIC** · **INDUCTION LOOPS** and **SYSTEM X**

FREE INSIDE! FREE INSIDE! FREE INSIDE!

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DECEMBER 1990 TO JANUARY 1991 VOL.10 No.41

EDITORIAL

Ho! Ho! Ho! It's that time of year once more when turkeys run for cover and your favourite magazine is packed fuller than Santa Claus' sack. It's also the start of Volume 10, so Happy Birthday to us. A lot has changed in ten years: integrated circuits have advanced in leaps and bounds; there's been the introduction of surface mount techniques and the invention of the Compact Disc, NICAM and HDTV. For readers of 'Electronics', the magazine is thicker; projects bigger and better; magazine pages are brighter and my hair is greyer! You may be asking has the Editor had too much Christmas Spirit or is he going to reveal all that's in this issue? For all of you who are eagerly awaiting part two of Compuguard, you can turn to page 8 and build the infra-red transmitter and receiver/switch unit. A Christmas issue wouldn't be complete without a seasonal project or two; there's the Christmas Star and the Zero Crossing Optoswitch to make Oxford Street's illuminations look tame! For TV-addicts there's a remote control to use with the *NICAM TV Tuner*. The MOSFET amplifier first appeared in Issue One of 'Electronics', it's here again, ten years on, in a revised form. There's an article on microcontrollers and the chance to win ferry crossings to France in an article about P&O, Ooh La La! Also the usual serials and regulars, plus a new column – Stray Signals – taking a humorous look at electronics. So what are you waiting for, put that mince pie down, read on and enjoy!

R. T. Smith

ABC 35,579

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PROJECTS

FEATURES

REGULARS

CORRIGENDA

August to September 1990 VOL.9 No.39
SSM2015 Microphone Preamplifier (LP42V)
Resistors R2 and R3 should be 6k8 and NOT 68k as indicated on the circuit diagram and parts list.
Bob's Mini Circuits – Signal Tracer
Inverting and non-inverting inputs (pins 2 and 3 respectively) on IC2 are shown with the pin numbers transposed.

NEWS Report

Radio Waves

Medium-wave radio reports the IBA has recently been enjoying a revival, with most of the ILR stations providing separate programming for their VHF and MF transmitters. As the number of new Incremental stations which only operate on medium-wave increases, attention has now turned to measures to improve AM receiver performance and even provide stereo.

The main complaint of AM listeners is poor sound quality, mainly due to the audio frequency response of most receivers. This results partly from the 9kHz channel spacing on medium-wave imposing a limit on the width of the upper and lower sidebands, which extend above and below the carrier frequency by at least the highest modulating frequency.

Some manufacturers already produce AM receivers with a bandwidth of 6kHz, because they are also designed to receive AM stereo transmissions, such as the Motorola stereo system C-QUAM (Compatible Quadrature Amplitude Modulation). This is currently being used in the U.S.A., Canada and Australia. As yet there is no world standard for AM stereo, but Britain will probably be the first in Europe to adopt a system, following tests which have taken place.

Early indications are that C-QUAM stereo is entirely compatible with mono equipment and, while the audio quality and interference immunity cannot be as high as for VHF/FM, the addition of stereo is a worthwhile benefit, at least in the main service area of a medium-wave transmitter. With about 20 million decoder chips supplied worldwide by Motorola and around 575 U.S.A. stations already using C-QUAM, the IBA is now liaising with U.K. receiver manufacturers in preparation for its introduction into the U.K.

Mercury Calls

A prototype light and compact PCN phone has been revealed by Mercury Personal Communications to be introduced when Mercury launches its new PCN service at the end of 1992. The comms company is investing over one billion pounds in creating a network which will serve some five million users. Details, Tel: 071-971-8125.

Mercury Callpoint are doing their best to overcome the problem of those few remaining non-working BT call-boxes in London. Following an agreement with London Underground, subscribers to the Mercury Callpoint service will now be able to make phone calls from any of the capital's 248 underground stations. Billed as 'the phone-box in your pocket', the Callpoint personal phone will operate within a 100 metre radius of a base unit site.

Meanwhile, Mercury has issued a new Personal Pocket Phone for cellular network users. The NEC P3 model is a lightweight, slim-line pocket phone

which readily converts into a hands-free carphone with an automatic answering facility. Battery life, a bain with most portable units, will stretch to 20 hours standby and 80 minutes talk-time. The unit is supplied with spare battery and desktop slow charger.

As watchful TV commercial viewers will have noticed, Cellnet has responded to rival announcements by more than doubling the capacity of its network within the London area bounded by the M25. In engineering terms, Cellnet's expansion within the area is the largest ever undertaken anywhere in the world. As well as introducing new voice-channels, the number of Cellnet cells will increase from 70 to 83. As a result, Cellnet's network in this region is now at least one and a half times the size of any alternative mobile phone network. Details, Tel: 0753-504-814.

Getting (and Losing) a Job in Computers

Atlanta may have been selected as the venue for the 1996 World Olympic Games, but not all locals are joining the cheering. Local high tech companies IBM and AT&T in common with many U.S. computer and comms companies such as Wang, Data General and Texas Instruments are eliminating thousands of jobs.

Also in the job-cutting activity league is British Telecom. Apart from shedding at least 6,000 managers, the corporation is said to be looking to lose some 80,000 employees over the next five years. If this were the case then the BT workforce would have been reduced by a third.

U.K. Education Minister John MacGregor has made some startling discoveries. Computing he says is seen as a technology-based subject and, therefore a male preserve. Calling for more girls to enter the computer profession, he said that "gender stereotyping" must stop. MacGregor provided computer companies with some helpful advice when recruiting women. They should make contact with local schools and colleges: Conduct a survey of the local female adult workforce; and introduce such staff facilities as career breaks, creches and part-time and home working.

Carefully steering his comments away from the role of women in computers, the Duke of Kent, president of the Engineering Council, announced two special environmental awards, one for individual engineers or technicians and the other for engineering teams. He also called for three or four engineers to be attached to every secondary school in the country in order to present students with a clear idea of engineering today. Details, Tel: 071-240-7891.

Dr Who?

British Satellite Broadcasting however struck back at Sky by scheduling a re-run of early BBC 'Dr Who' episodes. The Time Lords it seems are capable of switching TV channels as well as intergalactic time zones.

Solar Cell Technology

Sanyo Electric has announced what they claim to be a significant advancement in its amorphous solar cell technology with the introduction of a new flexible light-weight, solar cell film material. The new Amorton film, which is only 0·12mm thick and is flexible enough to form a small tube 10mm in diameter, can be shaped to conform to three-dimensional surfaces that would not normally accommodate fragile single or polycrystal cells, or conventional glass/stainless steel substrate flat panel cells. In addition, the film's light weight yields a power-to-weight ration of 200 milliwatts per gram, 10 times that of conventional glass-type cells. The product's light weight and flexibility allows amorphous solar cell technology to be applied to a new range of solar-powered, pollution-free products.

Call Me a Taxi

Landis & Gyr a company which seems determined to implant payphones in every nook and cranny, revealed at the recent TIA 90 event their latest assault. This is the new Agifon 50 Taxi payphone which can be installed at clubs and hotels enabling site owners to provide a contracted taxi service by means of a programmable button. Whatever happened to those whistle blowing commissionaires?

Chips with Everything

'Computergram' also reports that 1991 will see a double-digit growth rate in chip sales. Following a small increase this year, the Semiconductor industry sees sales rising 12·5% to $25,700m next year and a near 20% increase to $66,600m in the following year.

Meanwhile, a U.S. report is suggesting that state-of-the-art supercomputers in the year 2000 will have more than 256 processors, each no bigger than 16 cubic centimeters. These systems of the future reports 'Computerworld' will have one terabyte to 100 terabytes of memory and will boast speeds of 10 trillion floating-point operations per second. In the same period, chip densities will grow to one million gates per chip, compared with 1,000 gates per chip today.

The Mainframe Lives OK?

News of the month without doubt must be the announcement by IBM of its 'System/390 for the Nineties'. So great are the implications that the PA Consulting Group believe it will take several months to fully appreciate the significance. IBM in its most comprehensive announcement of products, features and functions in more than a quarter century, state that System/390 – with its broad array of product options – is designed to meet the needs of users in the '90s.

PA believe that the IBM release reinforces the continued existence of the mainframe. It could certainly do with a boost following the Pedder survey findings which suggest that 1998 saw the U.K. mainframe market falling by 6% to £1,197m. At the same time the business personal computer market grew by 25% to £2,846m.

Don't Blame the Hardware!

One company which will look kindly on the new IBM mainframe announcement will be Hardware Environmental Protection Agency (HEPA, who have recently established their European operational HQ in London. For HEPA the mainframe is far from being down and out. It is flourishing and needing installation protection procedures more than ever.

In fact a recent HEPA survey suggests that hardware itself now accounts for less than 25% of processing downtime, (from a figure of over 50% ten years ago) while site infrastructure is now responsible for over 50% of all installation operational problems. This figure says HEPA is set to increase to near 75% by 1995. According to Storm Larkins, chief executive of HEPA, "probably up to 90% of all computer rooms we survey have environmental problems. With even a short processing shutdown creating considerable havoc in the company, the need for our services is greater than ever". Details, Tel: 071-736-8312.

Micros Fight Back

Did you know that the number of PCs in the world now exceeds the population of the U.K. IBM, not surprisingly continues to dominate the market followed at some distance by Compaq. With the rest of the field accounting for the remaining 40%, competition is intense with price breaking rampant. Following the lead of Compaq who reduced prices across its micro board by some 22%, Tulip weighed in with a 10% price slash. The price slashing seems timely. According to Michael Naughton of consultancy Applied Network Research, several PC dealers have recently gone into liquidation and more are expected. Sales of PCs are sluggish and the situation could get worse before it gets better.

On the new product front, IBM lead the way with the introduction of PS/1 together with a host of integration products. The new 286 PC which

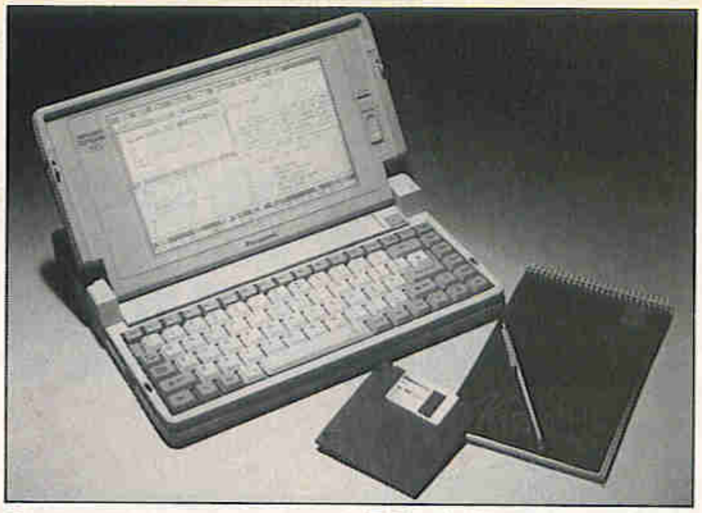
targets small businesses and the self-employed, which slots in below the popular PS/2, looks likely to become the industry pace setter.

Also pitching for the professional business market is the new Amstrad Generation 3 range comprising the PC3086, 3286 and 3386SX which benchmarks at over three times the speed of the standard IBM PC-AT in real life tests. For the first time, Amstrad has introduced metal casings for its PCs with increased emphasis being placed on component testing and quality control procedures. The new range spans the £549 to £1,599 price bracket. According to Malcolm Miller, Amstrad's Sales Director, desktop 386SX PCs are emerging as the standard equipment for the professional user and this trend can be tracked right across Europe. Details, Tel: 071-836-6801.

Toshiba Fights the Phantom Whistler

The curse of the whistling phone has been solved by Toshiba. It seems that fax machines programmed with a wrong number, will happily dial ordinary telephones. Anyone answering the calls gets greeted with a high-pitched, electronic whistle. The problem is that the fax machines having failed to make contact the first time, will continue at least twice more to get through. Now Toshiba are redesigning their fax equipment to make no repeat calls following the first incorrect call. Hopefully other fax equipment suppliers will take note (preferably a high-pitched one).

Meanwhile, network users can now send faxes directly from any application supporting HP laserjet and retain all the fonts and graphics that would normally be expected from a Laserjet printer. Users no longer have to leave their applications to send a fax, instead just two key strokes will allow them to enter coversheet information, access corporate or personal phone books and transmit their document in its original format at any time required. Details, Tel: Faxpress 071-721-7155.



Laptop Wars

Whether the newly released Panasonic Portable note-book PC emits ear-wrenching squeals has not yet been determined. Weighing-in at just 3·1Kg, (under 7lbs) the CF-270 PC features a standard 1Mb RAM expandable up to 5Mb, a 20Mb hard disk with an average access time of 25ms and either 720Kb or 1·44Mb 3·5in. disks and a screen size of 192mm × 118mm. Prices start at £2,599. Details, Tel: 0344-853550.

Epson have also released a new portable, the PC AX3/33 claimed to be the first 33MHz portable on the market. The portable runs MS-DOS 4·01 and comes with a standard RAM of 4MB expandable to 12MB. Weighing 7·85kg, it features a full 89-key keyboard and is priced at just under £6,000. Next year should see the arrival of a colour version. Details, Tel: 071-734-6030. Epson believes that with the high performance capabilities now available and increasing demands on desk space, portable products are becoming more and more important as replacements for traditional PCs, accounting for at least 20% of the total U.K. PC market by 1992. Toshiba agrees. With a 65·1% share of the U.K. portable PC market, the company is doubling output in order to meet the surging demand. Toshiba in fact also dominates the mains-powered sector with 85% of the market and holds the top three model places.

Ending with a Bang

Essex police thought they were destined for promotion when they called in the army bomb disposal unit in Brentwood, Essex. But that suspect package turned out to be – from the pieces retrieved from the blast – nothing more dangerous than a Toshiba laptop computer. Fortunately it was not attached to a lap at the time.

Last Straw

Those Iraqui's had better watch out. The Royal Scots Dragoon Guards, one of the regiments assigned to the Gulf, are the first cavalry regiment to fix cellular telephones to their saddles. But according to the industry newsletter 'Computergram', there is some consternation as to whether the equipment will withstand the somewhat bumpy ride afforded by a camel.

1992 and EMC

1992 has been hailed as the dawn to a new era of European trading, co-operation and market freedom; promising benefits to Joe Soap and Mega Corporation alike. However it is not entirely a rosy tale.

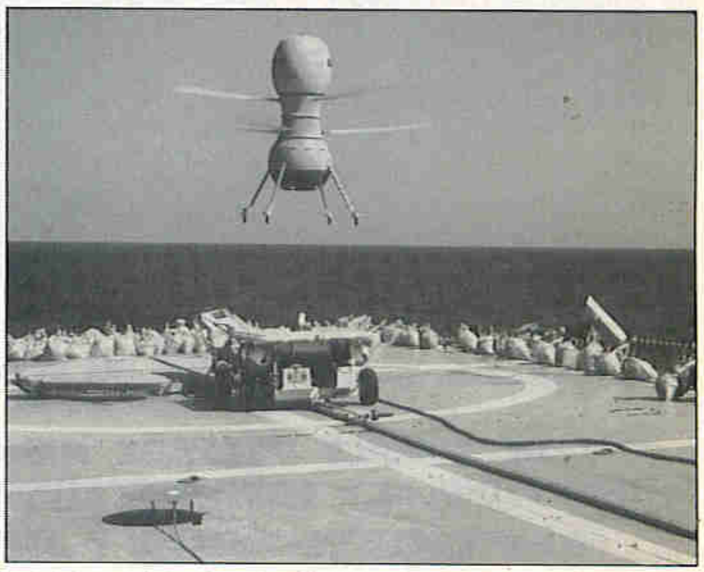
So what is so important about 1992 and EMC, well it is not a new updated version of Einstein's famous $E=MC^2$ formula. EMC is the abbreviation for electromagnetic compatibility, which in simple terms is the ability of electronic equipment to live harmoniously with the world at large. This encompasses both immunity to electromagnetic interference (EMI) and prevention of spurious radiation of electromagnetic interference.

It is the responsibility of the design engineer and manufacturer to ensure that EMI is neither radiated at unacceptable level by a piece of electronic equipment, nor its operation unduly affected by 'nearby' sources of EMI. In the past non-compatibility has caused unnecessary loss of life; in Japan two workers were killed when a computer controlled drilling machine malfunctioned due to EMI. Computer hardware, security surveillance and alarm equipment have all been responsible for interfering with the operation of cardiac pacemakers, killing the implantee. Less serious cases involve the malfunction of petrol pumps when CB radios are operated in the vicinity (not always to the benefit of the customer!).

The U.K. electronics industry is ill prepared for major new specifications that come into force on 1st January 1992. There are many excuses used to 'justify' the reluctance of early preparation; "The standards are not defined, so how can we meet standards that don't exist!" or "It probably won't be enforced, so we won't bother!" The issue here is that when the standards are published, the directives will become madatory. Anyone wishing to evade regulations, plead ignorance, etc, is likely to a stay at 'Her Majesty's pleasure'. In a similar way to the enforcement of Health and Safety requirements, the EMC regulations will be legally enforced with court action, fines and jail sentences. Although it is unlikely that an equivalent to TV detector vans will be introduced, the DTI will however investigate and uphold complaints. In the case of interference being introduced 'backwards' into the mains supply the D of E would become involved too.

The regulations cover all manner of equipment from car electronic ignition systems to personal computers, vacuum cleaners to oscilloscopes and many other items besides. It is interesting to note that a common complaint from radio amateurs' is the 'hash' produced by the U.K.'s ever enlarging cellular telephone network! It could be time for some big organisations to clean up their act.

Picture Caption Challenge



Just what on earth is going on here? Is it:

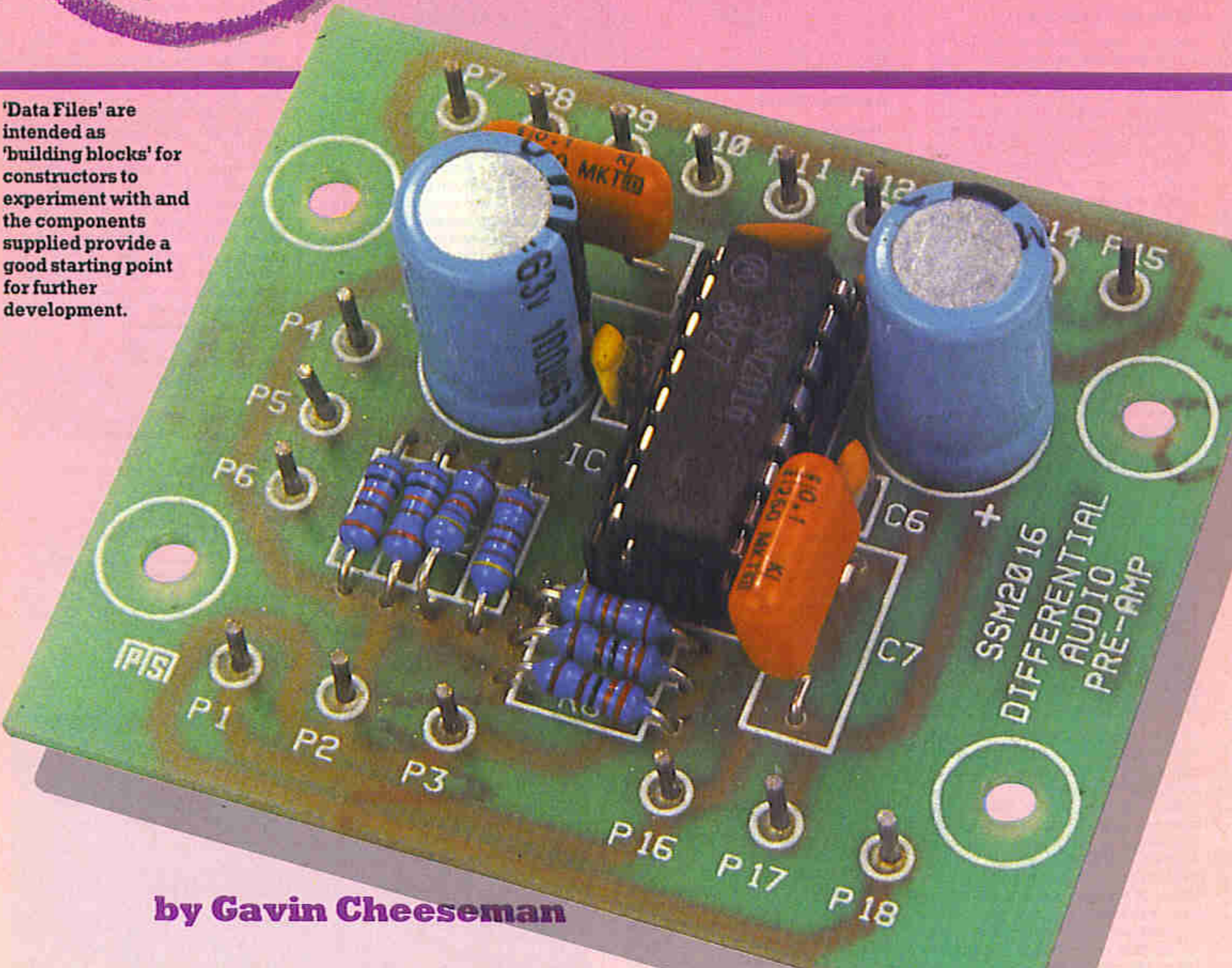
- ★ Richard Branson's latest trans-atlantic crossing attempt.
- ★ A satellite TV Detector Van.
- ★ A device for replenishing the ozone layer.
- ★ Filming of the latest Holywood blockbuster – Teenage Mutant Hero Bumble-bees.
- ★ Trials of a new high-tech way of beating traffic jams on the M25 London Orbital Car Park.
- ★ The Government's latest weapon against the Anti-Poll Tax movement.

Well, actually it is a Canadair CI-227 Sea Sentinel unmanned air vehicle (UAV) undergoing shipboard trials onboard a U.S. Ship at the Pacific Missile Test Centre near Los Angeles, California. The UAV successfully demonstrated take-off and landing on the ship which was travelling at six knots. The vehicle carried a television camera payload and provided real-time video transmission back to the ship.

DATA FILE

SSM2016 DIFFERENTIAL PREAMPLIFIER

'Data Files' are intended as 'building blocks' for constructors to experiment with and the components supplied provide a good starting point for further development.



by Gavin Cheeseman

FEATURES

★ WIDE SUPPLY VOLTAGE RANGE ★ LOW NOISE ★ HIGH SLEW RATE (10V/μs) ★ TRUE DIFFERENTIAL INPUTS ★ LOW DISTORTION

APPLICATIONS ▶▶▶ BALANCED INPUT STAGES

Introduction

The SSM2016 is a versatile differential amplifier IC which can be used in many applications including microphone preamplifiers and balanced input stages. The device will operate over a wide range of power supply voltages between $\pm$9V and $\pm$36V and is capable of output source and sink currents up to 40mA. Figure 1 shows the IC pinout and Table 1 shows some typical electrical characteristics for the device. The IC has a true balanced input and single ended output.

IC Description

Figure 2 shows the block diagram of the SSM2016. The IC operates as a true differential amplifier with feedback returned directly to the emitters of the input stage transistors. Using this system it is possible to achieve optimum noise and common mode rejection whilst retaining a high input impedance.

The IC uses an internal servo amplifier to control the input stage current, independent of common mode voltage.

Parameter	Conditions	Min	Typ	Max
Supply voltage		±9V	±15V	±36V
Supply current		12mA		16mA
Slew rate			10V/μs	
Output voltage swing	Load = 600Ω, ± 20V Supply	±15V	±17V	
Output current	Source	40mA	70mA	
	Sink	40mA	70mA	
Input current	RMS		350pA	550pA
Power supply rejection ratio		90dB	100dB	
Bandwidth (−3dB)	Gain = 100		>1MHz	
Differential mode input impedance	Gain = 100		3MΩ	
Total harmonic distortion	See Figure 4			

Table 1. Typical electrical characteristics.

Noise Performance

The SSM2016 is optimised for source impedances below 1k and under these conditions is capable of extremely good noise performance. As an example, the noise figure with 150Ω microphones is typically around 1dB. It should be noted however, that care is required to achieve optimum performance, as many factors influence the operation of the device. High source impedances should be avoided as this is a major cause of degradation in noise performance. A more subtle influence is that of temperature and power dissipation. The SSM2016 uses a copper lead frame package which aids heat dissipation but even so the best noise performance is achieved when driving light loads at low power supply voltages.

Inputs

The SSM2016 inputs are fully floating; however, care must be taken to make sure that both inputs have a DC bias connection which is capable of maintaining them within the input common mode range. There are several methods of achieving this condition and some examples are shown in Figure 3. The usual method is to ground one end of the transducer (Figure 3a). Depending which end of the transducer is grounded, the amplifier will either be inverting or non-inverting. An alternative method is to float the transducer and use two resistors to set the bias point as shown in Figure 3b. The value of the resistors should generally be kept below 10k to limit common mode noise. A balanced transducer may be connected directly to the IC

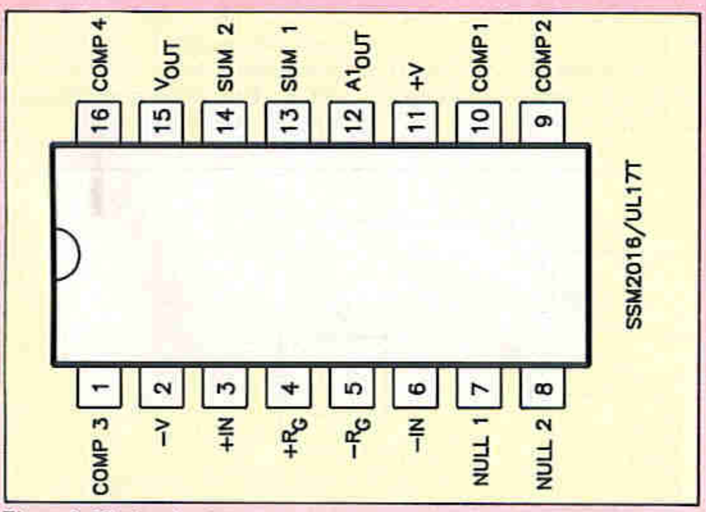


Figure 1. IC pinout.

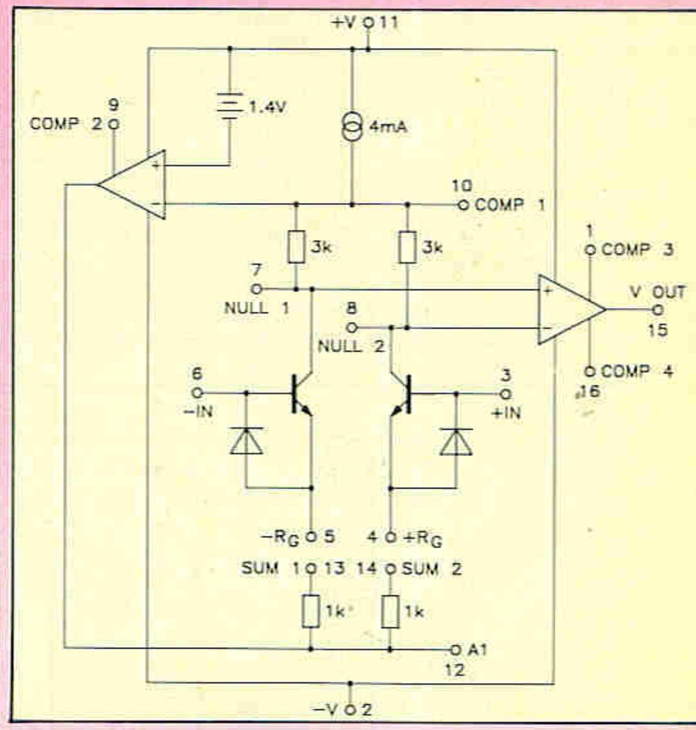


Figure 2. Block diagram.

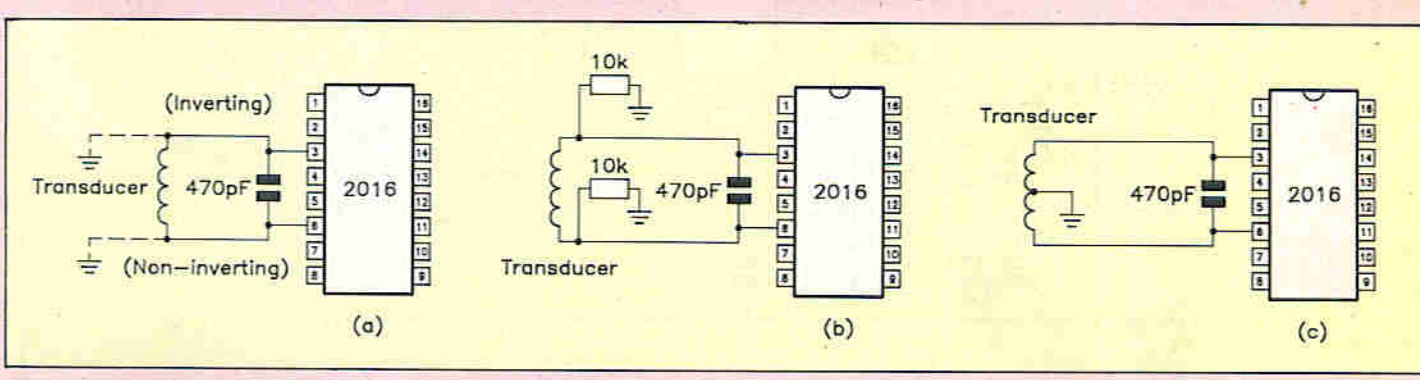


Figure 3. Connecting transducers for high noise immunity.

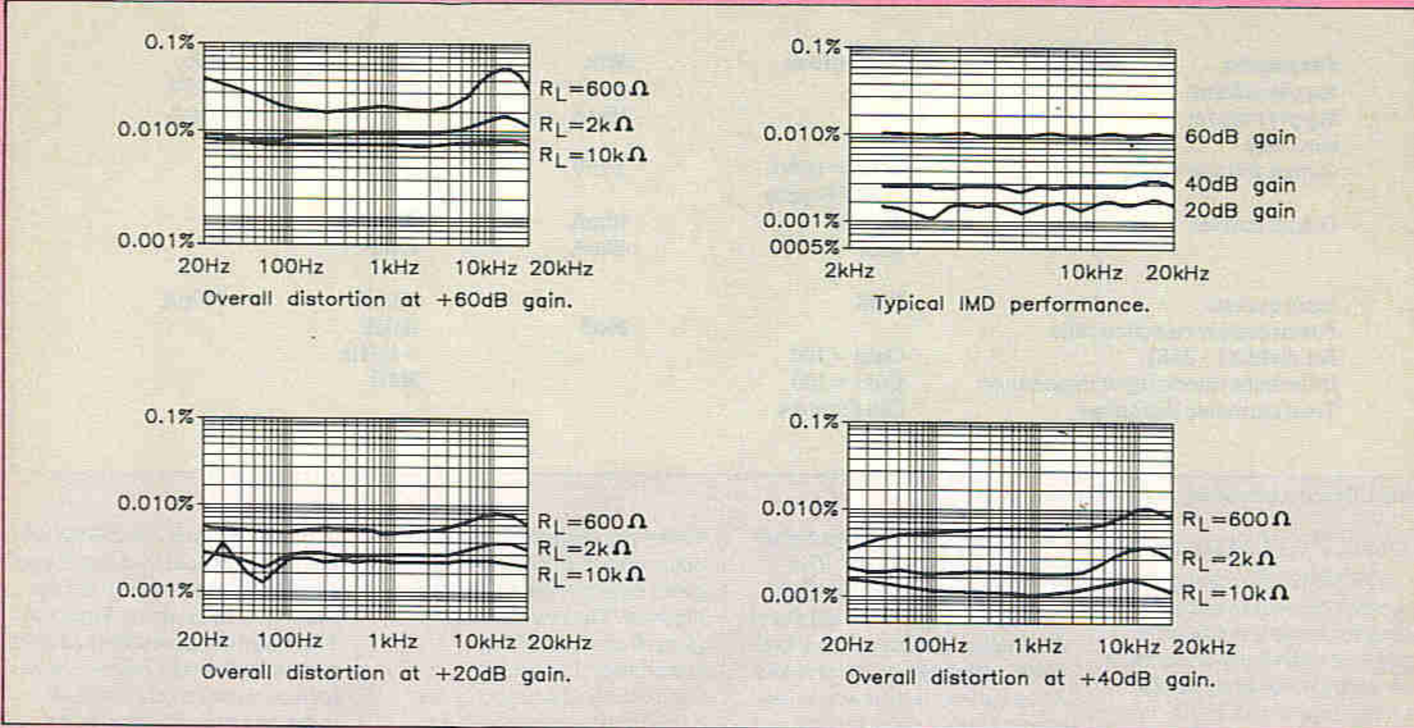


Figure 4. Typical distortion characteristics.

without any additional bias components as shown in Figure 3c, and this type of transducer provides the best degree of noise immunity.

Drive Capability

The device is capable of a relatively high drive level, and is designed to drive a jack field directly. A ± 18V power supply will typically allow a 600Ω load to be driven with a sine wave up to 10V RMS, although a ± 20V supply will give more comfortable headroom. Although the IC will operate at power supply voltages up to ± 36V, caution is required at all times to make sure that the package dissipation limits are not exceeded.

The −3dB bandwidth of the device varies with gain and is typically in excess of 1MHz at gains below 100. Slew rate is, however relatively independent of gain and is typically 10V/µs.

Figure 4 shows typical distortion characteristics for the IC under a variety of operating conditions. The graphs shown are based on an output level of 10V RMS and provide a reasonable indication of the IC's performance under worst case conditions.

Kit Available

A kit of parts, including a high quality fibreglass PCB with printed legend is available for a basic application circuit using the SSM2016. Because the circuit may be used in many varied applications some of the components used in the kit have been given arbitrary values suitable for general purpose use. In many cases it will be

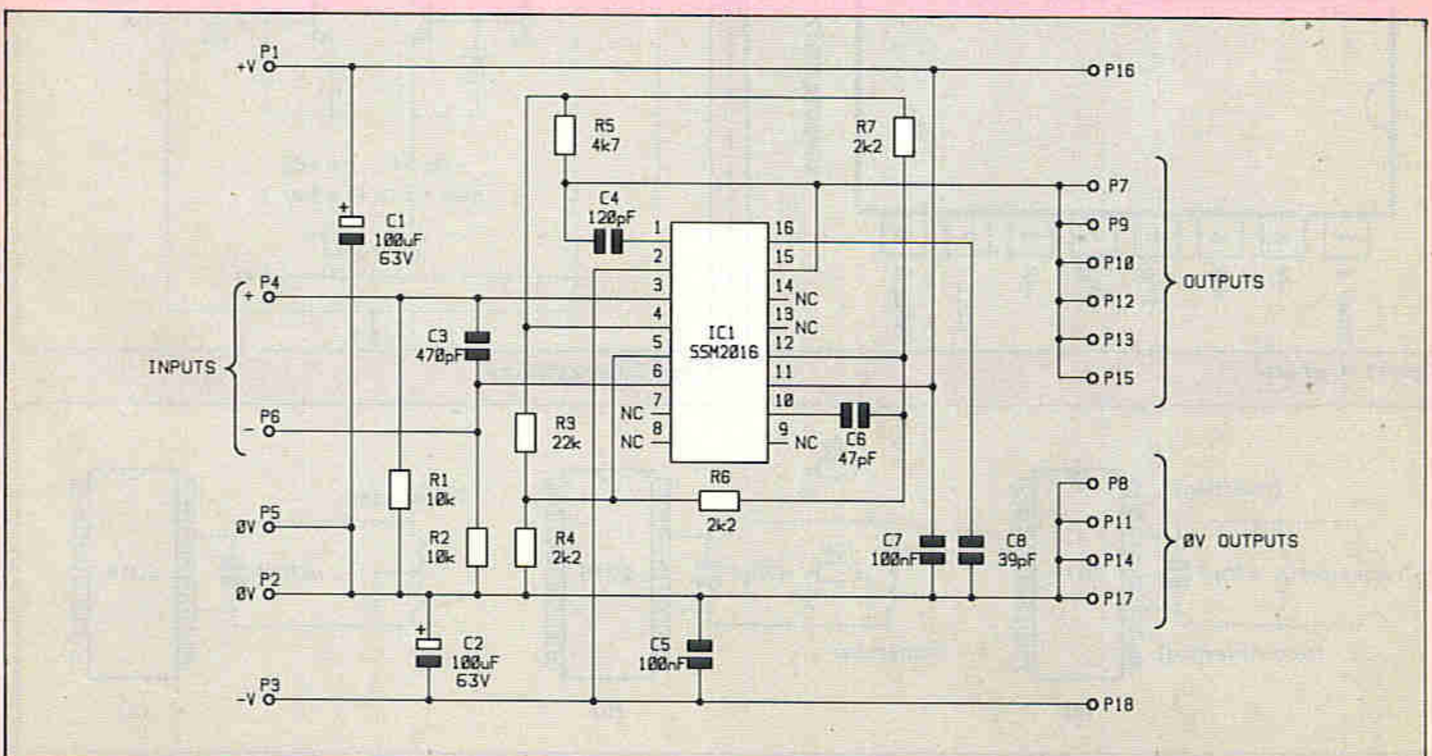


Figure 5. Module circuit diagram.

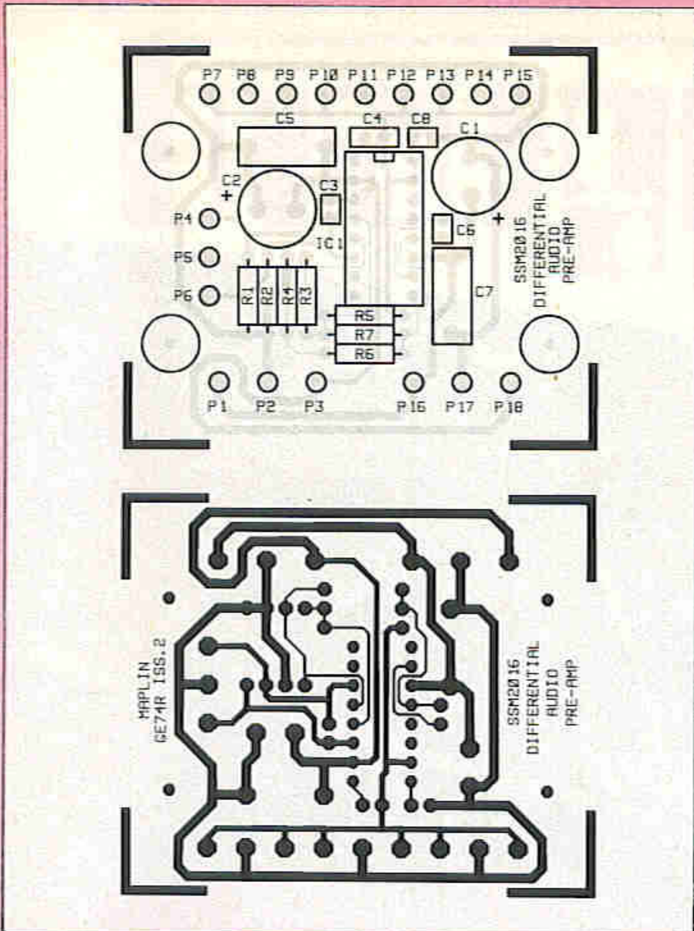


Figure 6. PCB legend and track.

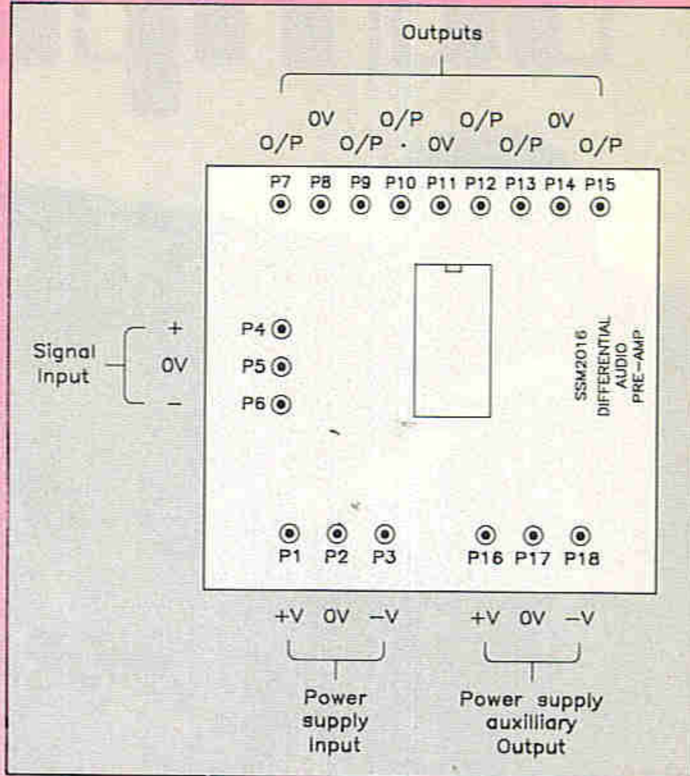


Figure 7. Wiring diagram.

necessary to make small changes in order to adapt the circuit for different purposes. Figure 5 shows the circuit diagram of the module and Figure 6 shows the legend.

The module operates from a split rail power supply of between ±9V and ±30V which is capable of supplying at least 50mA. It is important that the power supply is adequately decoupled to prevent mains derived hum from entering the circuit via the supply rails. Power supply connections are made to P1(+V), P2(0V) and P3(−V). Additional PCB pins P16(+V), P17(0V) and P18(−V) are included for power supply connections to auxiliary equipment; the maximum current drain from these pins should not exceed 1A.

In order to provide simultaneous outputs to several pieces of equipment, 6 output pins have been provided. The outputs are directly coupled and, to save space, each pair of outputs shares a common earth pin. Although output DC offsets are usually negligible it is recommended that capacitive coupling is used at the output in situations where small offsets are a problem. Input connections are made to P4(+input), P5(0V) and P6(−input) and outputs are taken from P7 – P15 (pins P8, P11 and P14 are output 0V connections). Figure 7 shows the wiring information.

Power Supply voltage	± 10V to ± 30V
Power Supply Current (Quiescent)	13mA (± 15V Supply)
Voltage gain	27dB
Maximum Input Voltage for Output Clipping (at 1kHz)	425mV RMS (± 15V Supply)

Table 2. Specification of prototype.

Using the Module

The circuit may be used in many different applications requiring a balanced input preamplifier. It is possible to set different gains by fitting resistors of different value in place of R3. Approximate gain of the circuit is given by the following formula where R3 to R7 are the values of the corresponding resistors in the circuit expressed in ohms:

$$G = \frac{R4 + R5}{R3} + \frac{R4 + R5}{R6 + R7} + 1$$

It should be remembered that the actual gain figures achieved may vary slightly from the calculated value due to component tolerances. The gain of the module is approximately 27dB using the resistor values supplied in the kit.

Finally, Table 2 shows the specification of the prototype preamplifier.

SSM2016 PARTS LIST

RESISTORS: All 0·6W 1% Metal Film

R1,2	10k	2	(M10K)
R3	470Ω	1	(M470R)
R4,5	4k7	2	(M4K7)
R6,7	2k2	2	(M2K2)

CAPACITORS

C1,2	100μF 63V PC Electrolytic	2	(FF12N)
C3	470pF Ceramic	1	(WX64U)
C4	120pF Ceramic	1	(WX57M)
C5,7	100nF Polyester	2	(BX76H)
C6	47pF Ceramic	1	(WX52G)
C8	39pF Ceramic	1	(WX51F)

SEMICONDUCTORS

IC1	SSM2016	1	(UL17T)

MISCELLANEOUS

P1-18	Pin 2145	1 Pkt	(FL24B)
	DIL Socket 16-Pin	1	(BL19V)
	PC Board	1	(GE74R)
	Constructors' Guide	1	(XH79L)
	Instruction Leaflet	1	(XK40T)

The above items are available as a kit:
Order As LP44X (SMM2016 Diff Preamp) Price £12.45

The following item is also available separately but is not shown in our 1991 catalogue:
Diff Audio Preamp PCB **Order As GE74R Price £5.45**

compuguard

Part 2 by Tony Bricknell

FEATURES

- ★ Fully programmable
- ★ Low power consumption
- ★ Infra-red arm/disarm remote control
- ★ Optional battery backup
- ★ Suitable for all negative earth vehicles
- ★ Microprocessor controlled
- ★ Alarm system can be activated with hazard lights flashing

Resumé

In part one of Compuguard we looked at the construction of the main control unit. In part two, the construction of an infra-red transmitter and IR receiver/sensor programming module is described, as well as full details on installing and operating the complete security system in your vehicle.

Infra-red Arm/Disarm Control

Many vehicle alarms presently on the market offer a radio remote arm/disarm. Unfortunately, most of these are illegal in this country, carrying fines of up to £2,000 for anyone caught using such a system!

Compuguard uses a completely legal infra-red remote that transmits a code just as difficult to 'crack' as its illegal radio counterparts!

Infra-red Transmitter Circuit Description

In addition to the circuit diagram shown in Figure 1, a block diagram is detailed in Figure 2. This should assist you when following the circuit description or fault finding in the completed unit.

The infra-red transmitter outputs an amplitude modulated carrier. This carrier is generated by IC2 and associated circuitry. IC1 provides a stream of data corresponding to the conditions set on pins 1 to 9 (high, low, or floating). This data is used to modulate the carrier and is transmitted from LD2 via TR1.

Infra-red Transmitter Construction

A glass fibre PCB has been chosen for maximum reliability and stability. To allow the PCB to fit into the key-ring remote case no IC sockets have been used, so please double check the orientation of the IC's before fitting as removal after incorrect insertion will almost certainly damage the chip! For further information on component identification and soldering techniques,

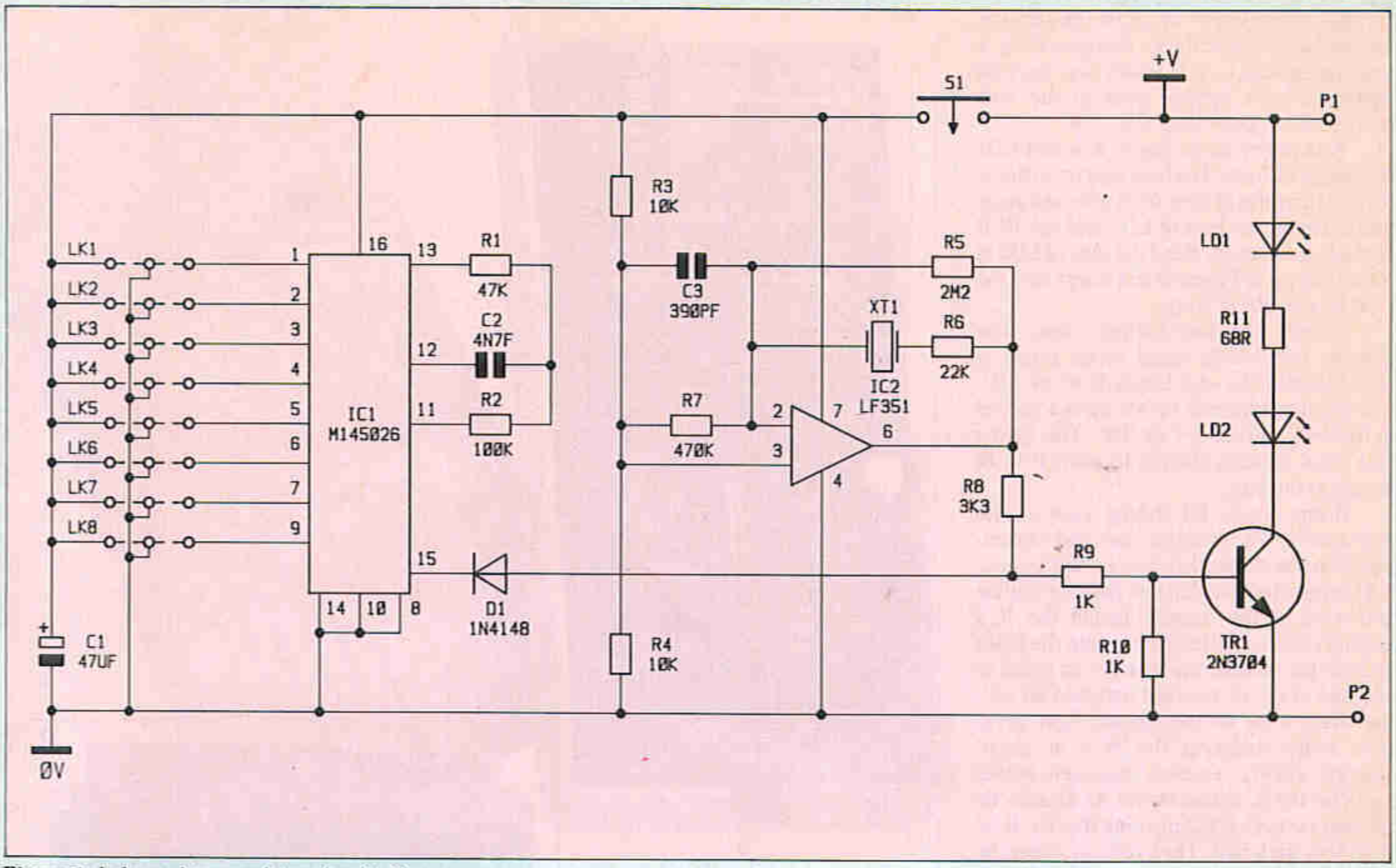


Figure 1. Infra-red transmitter circuit diagram.

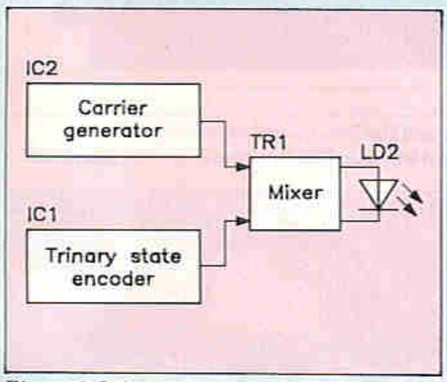


Figure 2. Infra-red transmitter block diagram.

please refer to the Constructors' Guide included with the kit.

Figure 3 shows the PCB, with printed legend, to help you correctly locate each item. The sequence in which the components are fitted is not critical, however the following instructions will be of use in making these tasks as straightforward as possible.

Start by fitting resistors R1 to R11, taking note that R5 is a larger, metal film resistor. Using off-cuts from the leads of these resistors, insert link LK9. LK1 to LK8 set up the code transmitted. With reference to Figure 4, there are three ways of connecting the links (well, two ways, the third is to leave them out). The purpose of these codes is to make your transmitter 'unique' so that only you will be able to control your alarm. If you are constructing several of these alarms, each unit must have a different code or one transmitter will control several alarm systems!

Insert S1 and XT1, bending the crystal flush to the PCB as per the legend.

Insert and solder C1 to C3 taking care of the orientation of C1. The polarity of this capacitor is shown by a plus sign (+) matching that on the PCB legend. However,

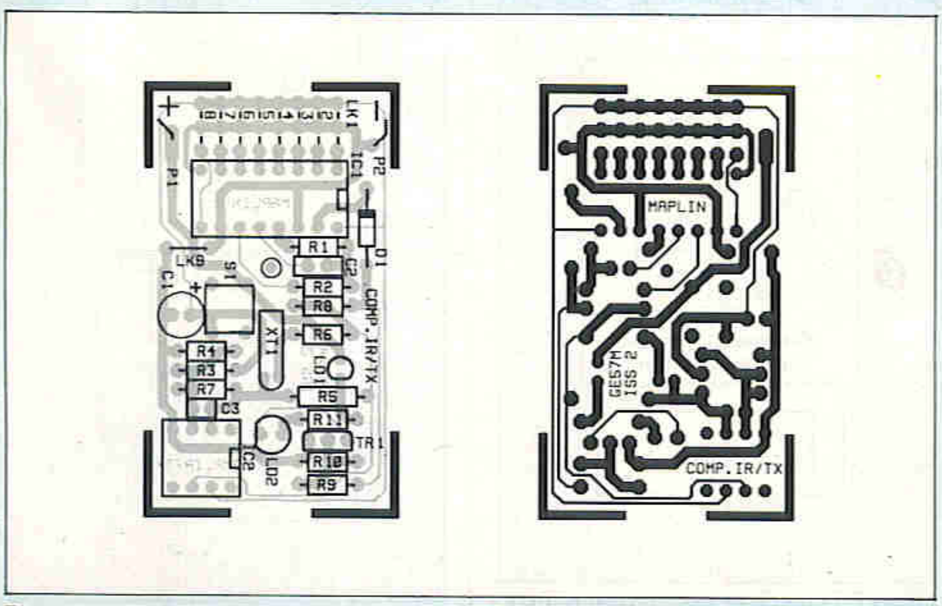


Figure 3. PCB and legend.

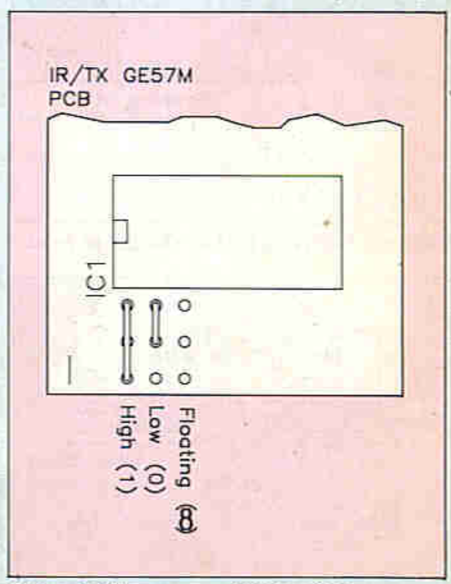


Figure 4. Three ways of fitting links LK1 – LK8.

on the actual body of most electrolytic capacitors the polarity is designated by a negative symbol (−), in which case the lead nearest to this symbol goes in the hole nearest the edge of the PCB.

With reference to Figure 5, insert LD1 at a height of 7mm. The best way to do this is to cut a thin strip of card 7mm wide and place this between the legs of LD1 and the PCB whilst it is soldered. Bend the legs of LD2 at 90° as shown in Figure 6 and insert into the PCB at a height of 3mm.

Identify the two battery clips. The positive terminal (a small metal plate) is soldered into the slot labelled '+' or 'P1'. The negative terminal, or 'spring' is soldered in the hole marked '−' or 'P2'. The spring may need bending slightly to allow it to fit snugly in the box.

Insert diode D1 taking care of its orientation. The band at one end corresponds to the thick white line on the legend. TR1 is inserted matching its package outline with that of the legend. Install the IC's making sure that all the pins go into the holes and the pin number one marker or notch at one end of the IC package matches up with the white block on the legend. Take *great* care while soldering the IC's in place, allowing several seconds between solder joints for the IC to cool down! As a guide, do the four corners first, ensuring that the IC is flush with the board. Then you can solder the remaining pins.

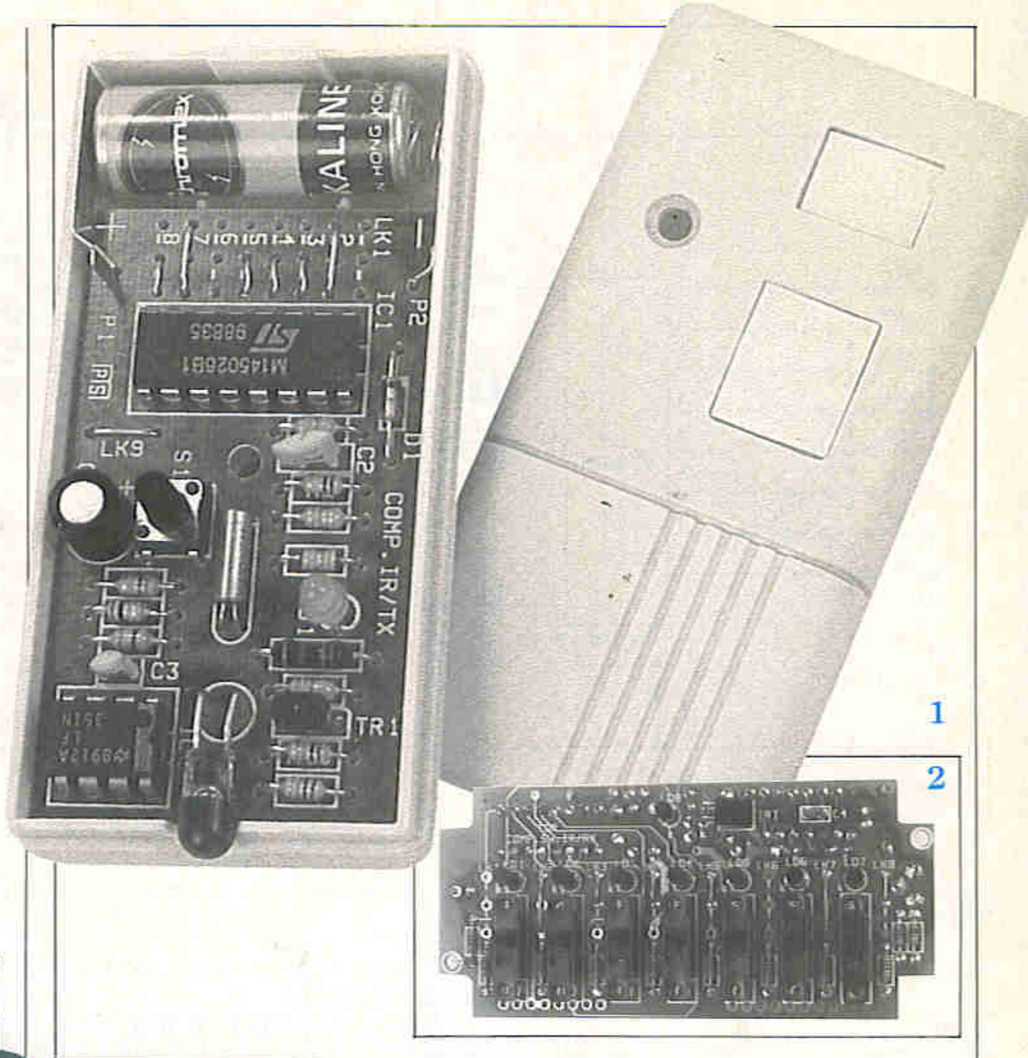


Photo 1. The Infra-red Transmitter Unit with PCB and Battery installed, prior to final assembly of the case. Inset: Photo 2. The assembled Infra-red Receiver and Switch Unit PCB.

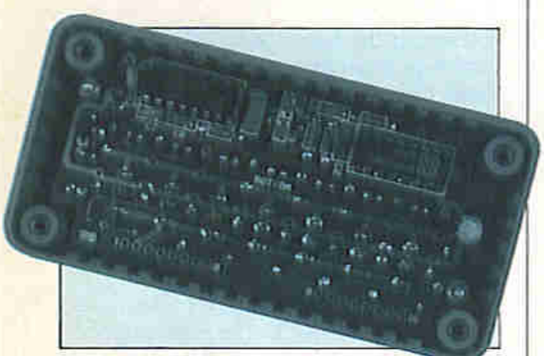


Photo 3. The Infra-red Receiver and Switch Unit PCB fitted into its box.

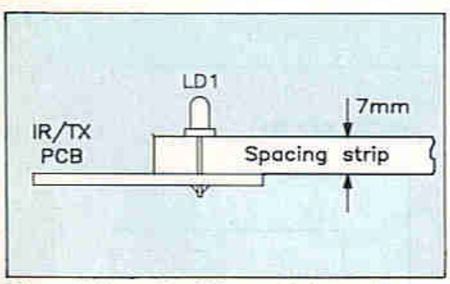


Figure 5. Inserting LD1 at a height of 7mm.

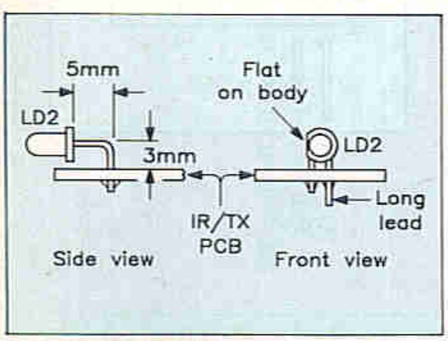


Figure 6. Fitting LD2.

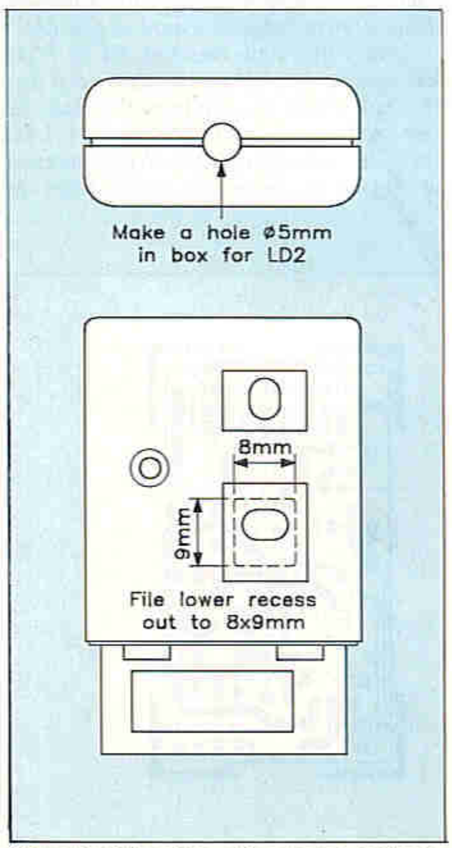


Figure 7. Filing dimensions for transmitter box.

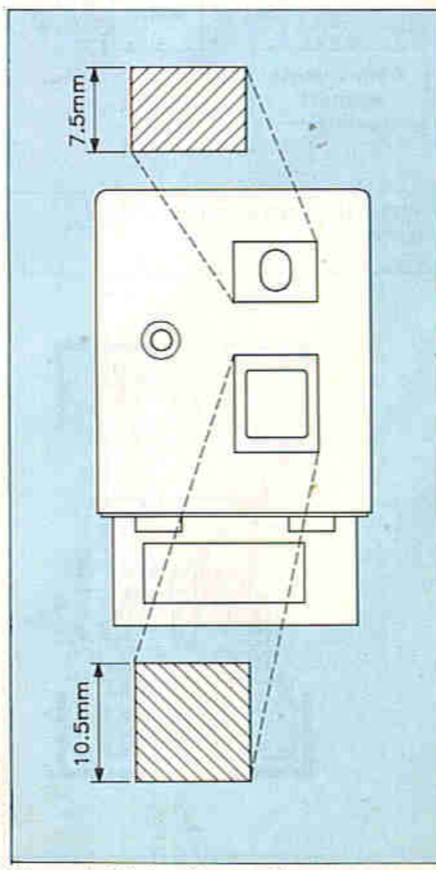


Figure 8. Fitting the membrane.

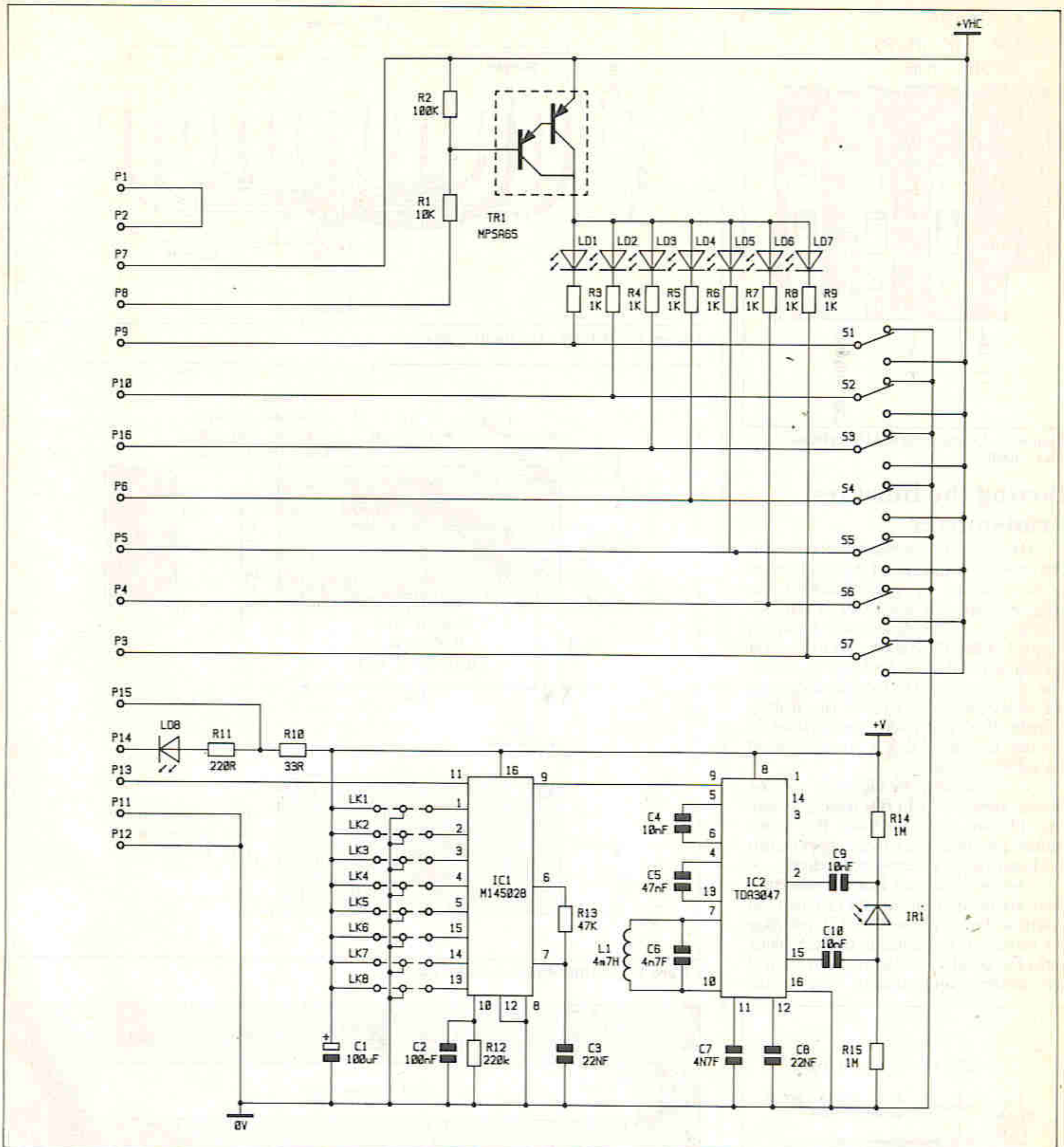


Figure 9. Sensor programming/IR receiver circuit diagram.

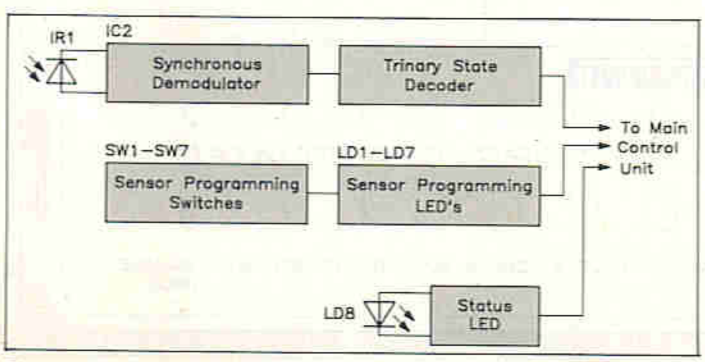


Figure 10. Sensor programming/IR receiver block diagram.

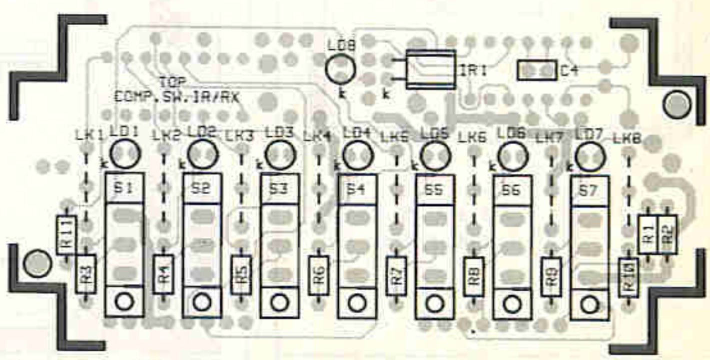


Figure 11. PCB and legend.

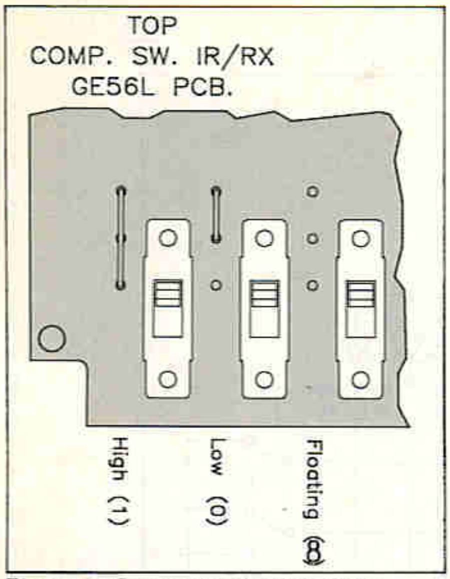


Figure 12. Connecting the IR Rx links LK1–LK8.

Boxing the Infra-red Transmitter

If the remote key-ring box comes with two switch actuators fitted then these need to be removed by pulling/breaking the actuator shaft. File the lower of the two inserts out to the dimensions shown in Figure 7. A 5mm hole also needs to be cut in the top end of the box for LD2, as shown. This is best achieved by carefully filing each half of the box with a round file, making frequent checks by placing the PCB inside the box to ensure that a correctly sized cut-out is achieved.

With reference to Figure 8, cut the flexible membrane into two pieces, 7·5mm and 10·5mm long. Remove the paper backing and stick them into the upper (small) and lower (large) recesses respectively.

Double check your PCB to make sure there are no dry joints or short circuits and assemble the box around the PCB, inserting the battery (not supplied in the kit) taking care of its polarity (marked on the bottom of the battery compartment). The whole

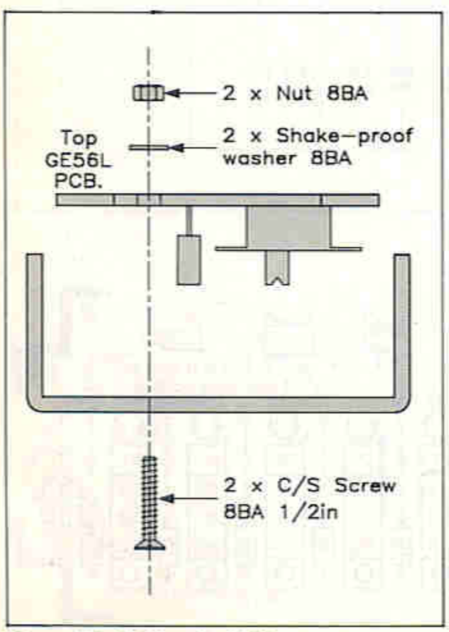


Figure 15. Fitting the PCB.

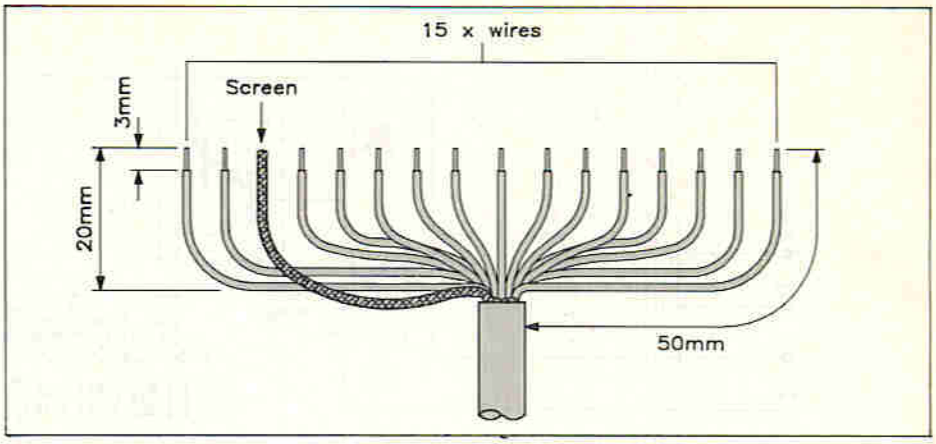


Figure 13. Stripping the multi-core cable.

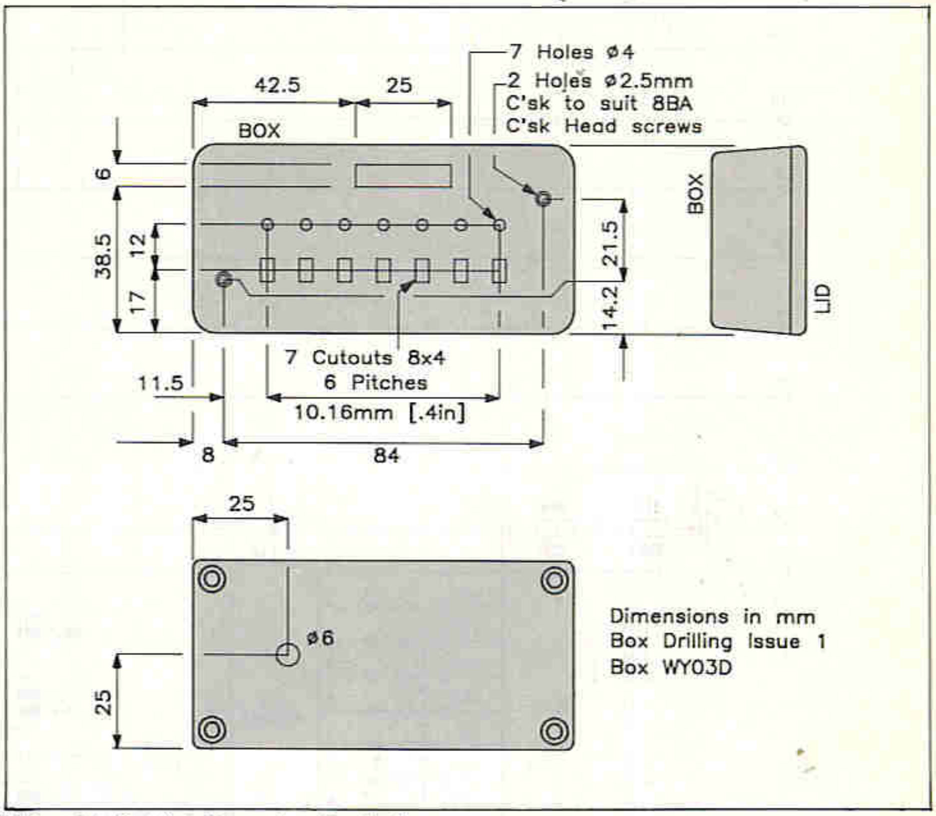


Figure 14. Cutting dimensions for the box.

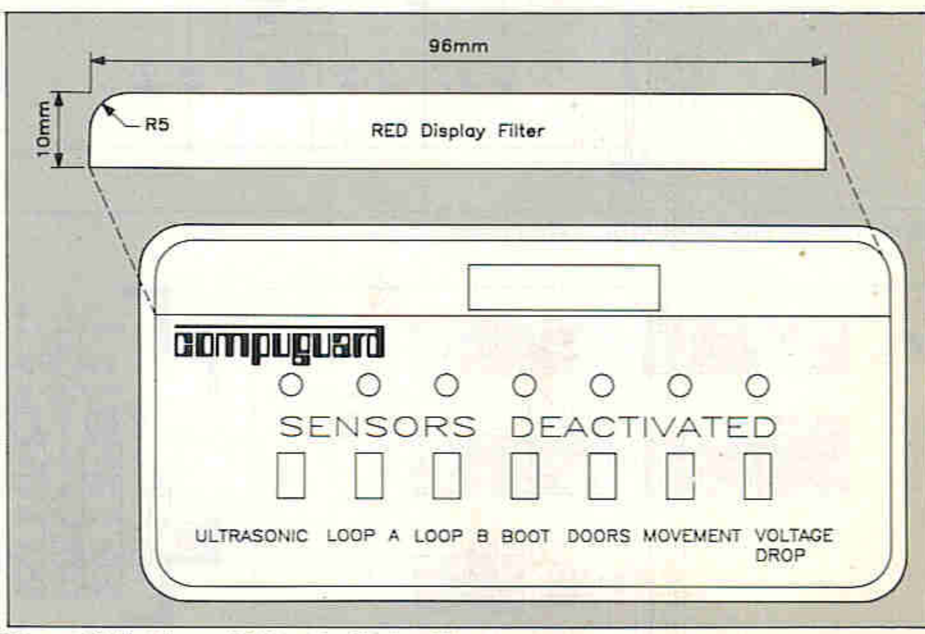


Figure 16. Cutting and fixing the display filter.

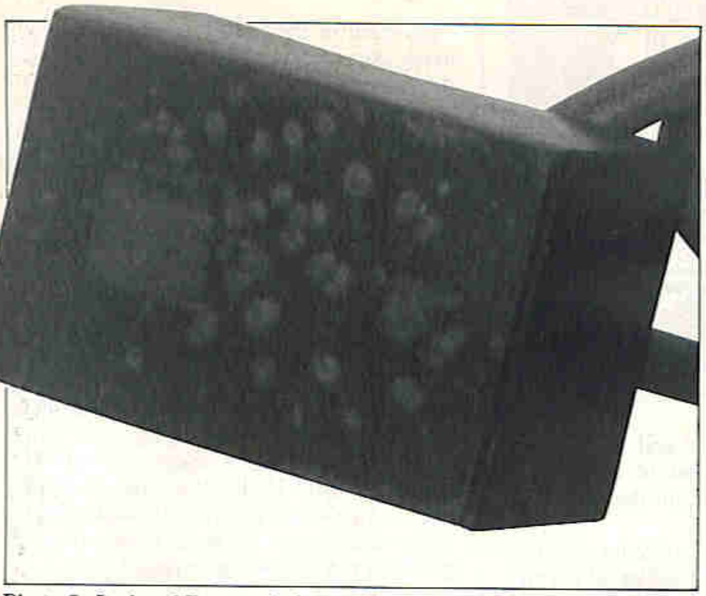


Photo 5. Optional Remote Infra-red Receiver.

Switch-IR/RX PCB	Colour Used	Compuguard Main PCB
1		TB1-4
2		TB1-3
3		TB1-8
4		TB1-7
5		TB1-6
6		TB1-5
7		TB1-2
8		TB1-1
9		TB2-1
10		TB2-4
11		TB2-5
12		TB2-8
13		TB2-7
14	- Screen	TB2-8
15		TB2-2
16		TB2-3

Table 1. Connection of the 15-way cable.

assembly is screwed together with the single screw provided.

The only thing left to do now is to depress the larger membrane upon which the red LED LD1 should flash very quickly.

Photo 1 shows the Infra-red Transmitter Unit with PCB and Battery installed prior to final assembly of the case.

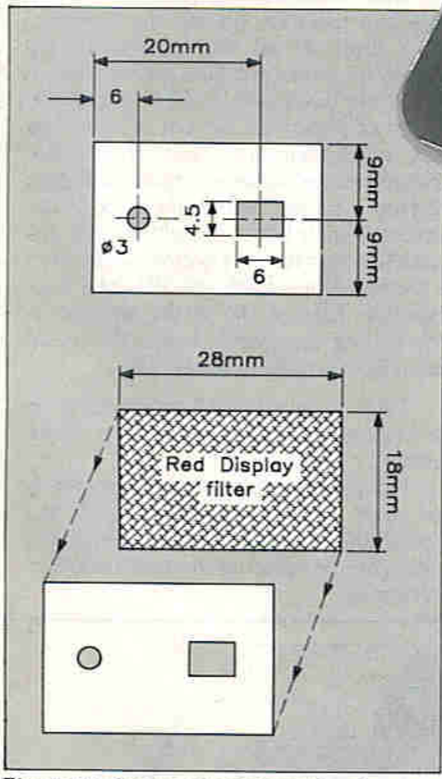


Figure 17. Constructing the optional remote IR receiver.

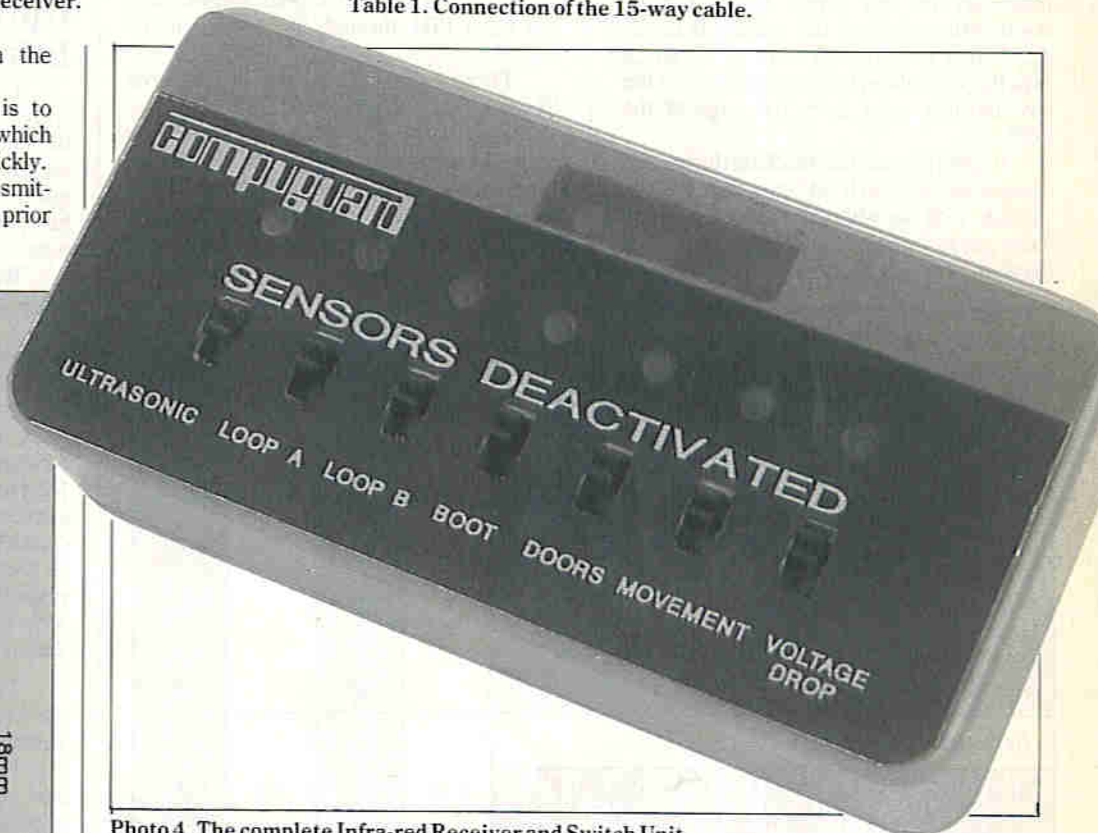


Photo 4. The complete Infra-red Receiver and Switch Unit.

Sensor Programming/ IR Receiver Circuit Description

A circuit diagram is shown in Figure 9, as well as a block diagram in Figure 10 to complement the circuit description and assist fault finding on the completed unit.

Infra-red transmissions from the key-ring are picked up by IR1 and fed into IC2 which strips off the carrier leaving only the bare digital data stream. This is fed into IC1 and if the code received is the same as that set on pins A1 to A9, the output pin 11 becomes active.

LED LD8 is used by the main control unit to indicate the status of the alarm system. It illuminates on receipt of a valid arm/disarm code from the IR-Tx, flashes when the alarm is armed, and remains constantly on when the alarm has been triggered.

SW1 – SW7 control which sensors are deactivated. Under control of the main unit, as soon as the position of one of the switches is altered, TR1 switches on, allowing LD1 – LD7 (depending on the position of the switches) to illuminate. If the switches are left unaltered for twenty seconds, TR1 is turned off to conserve battery power.

Sensor Programming / Infra-red Receiver Construction

For maximum reliability, a glass fibre PCB of the double-sided, plated-through hole type has been chosen, see Figure 11. However, because the holes are plated through, removal of a misplaced component will be quite difficult, so please double-check each component type, value and its polarity where appropriate, before soldering!

With reference to Figure 12, start construction by inserting links LK1 – LK8. These links must match those previously set on the infra-red transmitter. Next, insert and solder resistors R1 – R11, switches S1 – S7, and C4. Insert LD1 – LD7 at a height of 3mm above the PCB. Insert LD8 and IR1. do not bend IR1 to match the legend just yet.

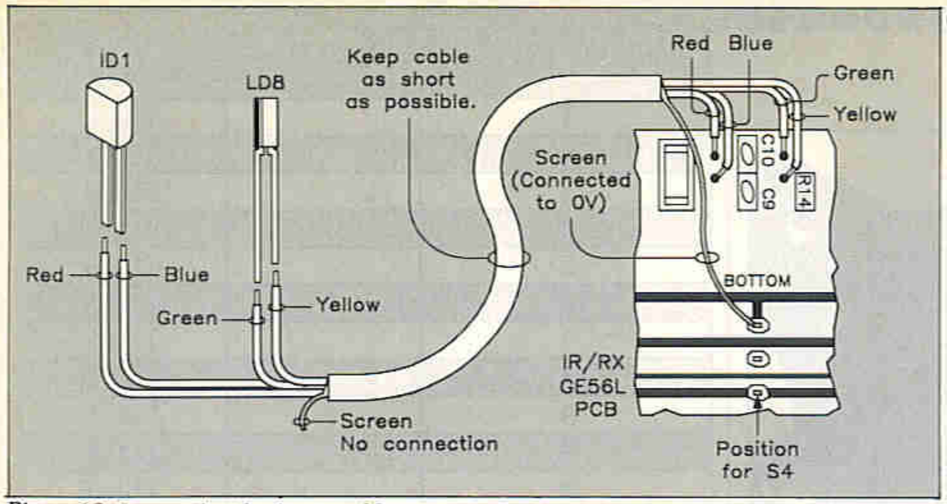


Figure 18. Connecting the 4-core cable.

Turn the board over and solder all the remaining components, ensuring the package outline of TR1 matches that shown on the legend. Take care of the polarity of C1, that the plus sign (+) on the PCB legend matches that on the capacitor's body. However, on the actual body of most electrolytic capacitors the polarity is designated by a negative symbol (−), in which case the lead nearest this symbol goes in the hole furthest away from the edge of the PCB.

Insert IC1 and IC2 matching the pin one designator or notch at one end of the package with the white block on the legend. Take *great* care while soldering the IC's; because of the depth of the box chosen, no IC sockets can be used and, as before, several seconds will have to be allowed between each solder joint for the IC to cool down!

Double check your work for any dry joints or stray strands of solder which will cause short circuits and bad connections, and bend PD1 through 90° to match the legend.

Photo 2 shows the assembled Infra-red Receiver and Switch Unit PCB.

Strip a length of 15-way multi-core cable as shown in Figure 13, and make connections to the switch assembly PCB, holes 1-8 and 9-16. Because, unfortunately, would-be thieves could be reading this article, no colours are given for the connection of the multi-core cable so that every alarm system is unique, but note that the screen must be connected to hole number 14. Using a pencil, mark on Table 1 the colours *you* have chosen for connections 1-16. This will be essential when connecting the other end to the main control unit.

Boxing the Infra-red Receiver/Switch Assembly

Drill and file an ABS Box 2002 to the dimensions given in Figure 14. Insert the multi-core cable through the 6mm hole and fix the PCB to the box using ½in. 8BA countersunk screws, washers, and nuts as shown in Figure 15. Fix the screened panel over the switches. Cut the red display filter to the dimensions shown in Figure 16 and glue it to box above the screened panel.

Optional Remote Infra-red Receiver

Depending on the position of installation within the passenger compartment, it may be required to mount the infra-red receiver/switch assembly out of sight. A remote infra-red receiver diode/status LED will have to be mounted in a potting box as follows:

With reference to Figure 17, cut two holes in a miniature potting box (LH56L). Cut a strip of red display filter to the dimensions shown and glue over the top of the potting box (using FL43W or similar). Instead of soldering LD8 and IR1 onto the PCB, attach them to the end of a length of 4-core screened cable as shown in Figure 18. Drill a second hole in the back of the switch assembly box to accept this cable and carefully solder it to the bottom of the PCB as shown. Place LD8 and IR1 into their respective holes in the potting box and fill with potting compound. Leave the entire assembly overnight to harden fully.

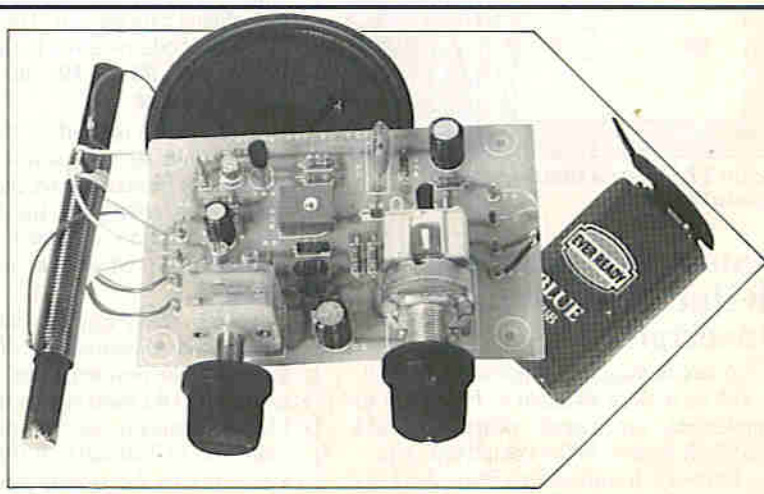
Table 2 gives the full specification for the complete Compuguard Vehicle Alarm System.

Full details on how to install the system into your car, testing procedures and general information on the upkeep of the system are provided on the leaflet supplied with the kit.

Main Unit and Infra-red Receiver	MIN	TYP	MAX	UNITS
Supply Voltage	10	12	15	V
Supply Current Disarmed @ 12V	13·7	13·8	100	mA
Supply Current Armed @ 12V	14	19	28	mA
Back-up Battery Charge Current		6		mA
Operating Time on Battery Back-up (Depending on Siren)	2	18	25	hours
Central Locking Lock/Unlock Pulse Duration LK1 Installed		1·5		sec
Central Locking Lock/Unlock Pulse Duration LK2 Installed		2·5		sec
Exit Delay		30		sec
Alarm Cycle Time		60		sec
Infra-red Transmitter				
Supply Voltage	8·5	12	15	V
Supply Current @ 12V		27		mA

Table 2. Specification of prototype Compuguard system.

Watch as you build...



COMPUGUARD I/R RX PARTS LIST

RESISTORS: All ⅓W Carbon Film			
R1	10k	1	(U10K)
R2	100k	1	(U100K)
R3-9	1k	7	(U1K)
R10	33R	1	(U33R)
R11	220R	1	(U220R)
R12	220k	1	(U220K)
R13	47k	1	(U47K)
R14,15	1M	2	(U1M)
CAPACITORS			
C1	100μF 10V Minelect	1	(RK50E)
C2	100nF Minidisc	1	(YR75S)
C3,8	22nF Ceramic	2	(WX78K)
C4,9,10	10nF Ceramic	3	(WX77J)
C5	47nF Poly Layer	1	(WW37S)
C6,7	4n7F Ceramic	2	(WX76H)
SEMICONDUCTORS			
TR1	MPSA65	1	(QH61R)
IC1	M145028	1	(UJ51F)
IC2	TDA3047	1	(UL25C)
LD1-8	Shape LED C2 Red	8	(YH72P)
IR1	Infra-red Photodiode	1	(YH71N)
MISCELLANEOUS			
L1	4·7mH Choke	1	(UK80B)
SW1-7	SP Slide	7	(FF77J)
	ABS Box 2002	1	(WY03D)
	Compuguard I/R Rx Panel	1	(JR73Q)
	Compuguard I/R Rx PCB	1	(GE56L)
	Red Display Filter	1	(FR34M)
	4 Pairs 1in. Velcro	1	(FE45Y)
	C/S Screw 8BA × ½in.	1 Pkt	(LR00A)
	Nut 8BA	1 Pkt	(BF19V)
	Shake Washer 8BA	1 Pkt	(LR01B)
	Constructors' Guide	1	(XH79L)
	Instruction Leaflet	1	(XK35Q)
OPTIONAL (Not in Kit)			
	Potting Box Miniature	1	(LH56L)
	Potting Compound 50g	1	(FT17T)
	Quickstick Pads	1 Strp	(HB22Y)
	Multi-Core 15-way	As Req	(XR28F)
	Multi-Core 4-way Screened	As Req	(XR25C)

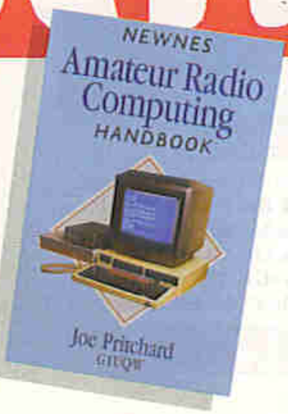
The above items, excluding Optional, are available as a kit:
Order As LP23A (Compuguard IR Rec/Sw) Price £19.95
The following items are available separately:
Compuguard I/R Rx Panel **Order As (JR73Q) Price £2.95**
Compuguard I/R Rx PCB **Order As (GE56L) Price £5.45**
Compuguard Rx/Tx Leaflet **Order As (XK35Q) Price 50p** *NV*

COMPUGUARD I/R TX PARTS LIST

RESISTORS: All ⅓W Carbon Film (Unless specified)			
R1	47k	1	(U47K)
R2	100k	1	(U100K)
R3,4	10k	2	(U10K)
R5	2M2 Metal Film	1	(M2M2)
R6	22k	1	(U22K)
R7	470k	1	(U470K)
R8	3k3	1	(U3K3)
R9,10	1k	2	(U1K)
R11	4R7	1	(U4R7)
CAPACITORS			
C1	47μF 16V Minelect	1	(YY37S)
C2	4n7F Ceramic	1	(WX76H)
C3	390pF Ceramic	1	(WX63T)
SEMICONDUCTORS			
D1	1N4148	1	(QL80B)
TR1	ZTX300	1	(QL46A)
IC1	M145026	1	(UJ49D)
IC2	LF351	1	(WQ30H)
LD1	Mini Red LED	1	(WL32K)
LD2	Infra-red Emitter	1	(YH70M)
MISCELLANEOUS			
SW1	Tact Switch Type A	1	(JR89W)
XL1	Crystal 32·768kHz	1	(UJ02C)
	Compuguard Tx PCB	1	(GE57M)
	Keyring Remote Case	1	(JR90X)
	Remote Case Panel	1	(JR92A)
	Constructors' Guide	1	(XH79L)
	Instruction Leaflet	1	(XK35Q)
OPTIONAL (Not in Kit)			
	12V Lighter Battery 23A	1	(JG91Y)

The above items, excluding Optional, are available as a kit:
Order As LP24B (Compuguard IR Tx) Price £9.95
The following items are available separately:
Tact Switch Type A **Order As (JR89W) Price 36p**
Compuguard Tx PCB **Order As (GE57M) Price £2.25**
Keyring Remote Case **Order As (JR90X) Price £1.20**
Remote Case Panel **Order As (JR92A) Price 32p**

NEW BOOKS



Newnes Amateur Radio Computing Handbook

by Joe Pritchard

Showing how computers can be used by radio amateurs or short wave listeners, and how the enthusiast can spend as much time 'listening' to signals by reading text off a computer display as by donning the headphones. The widespread availability of small computers has changed the lives of these radio enthusiasts. 'Old' modes of communication, such as morse code and even voice, have been joined by new, computer-based methods of communication. In addition, older modes of machine to machine communication, such as radio teletype (RTTY) are now being performed by silent computers rather than large, oily, clanking teletype machines.

Computers are also used as design circuit tools, to replace test equipment, to act as filing clerks and even to control receivers and transmitters. Listeners use them to decode meteorological information and signals from amateur radio satellites. Computers are even used to predict which frequencies to use for the best results.

Contents include basic radio principles; basic computer principles; software for electronic design; logkeeping and QSL card software; satellite and geographical software; miscellaneous software; interfacing the computer to the radio; morse code; RTTY and ASCII; AMTOR; SSTV and FAX; packet radio; commercial decoders; controlling a radio with a computer; computer assisted circuit development and appendices.

1990. 214 x 138mm. 363 pages, illustrated.

Order As WT17T (Amateur Radio Comp) Price £14.95 NV

Electronic Test Equipment Handbook

by Steve Money

In most applications of electronics, test instruments are essential for checking the performance of a system or for diagnosing faults in operation, and so it is equally important for the amateur projects designer and builder to understand how the basic test instruments operate and how they should be used as it is for the professional engineer or technician.

In this book the principles of the various types of test instrument are explained in simple terms with a minimum of mathematics. The hobbyist's biggest problem is most probably that, unlike his professional counterpart in the industry, he does not have ready access to a vast armoury of sophisticated or otherwise test and measurement instruments, but test gear of some description is, as experience will show, vital even for the most modest home-brewed circuit. The problem is going to be what to choose given a limited budget. Here you will find described a wide selection of test instruments ranging in complexity from the humble continuity tester through analogue and digital multimeters to the next most popular item, the oscilloscope, followed by signal generators and finishing with computer controlled testing equipment. By reading this book you will be able to ascertain precisely what you need for your own particular 'field'.

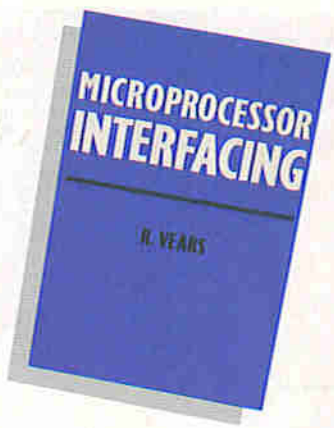
1990. 216 x 134mm. 206 pages, illustrated.

Order As WT18U (Elec Test Equip Hdbk) Price £8.95 NV

Microprocessor Interfacing

by R. Vears

Principally this book covers the BTEC level NIII Microprocessor Interfacing syllabus U86/335, and can be regarded as a comprehensive textbook on the subject of interfacing microprocessors to external peripherals and sensors. The aim is to provide the reader with a foundation in microprocessor interfacing techniques, in both hardware and software, so that interface problems can be identified and solutions devised. Each topic is presented in a way which assumes, on the part of the reader, some prior knowledge of electronics and, as far as programming is concerned, some familiarity with assembly. The text concentrates on the widely used 6502,

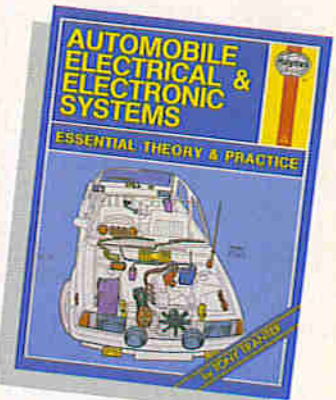


Z80 and 6800/6802 microprocessor families, and so is directly applicable to many 8-bit home microcomputers and 'breadboard' systems using these popular microprocessors. Basic details of typical interfacing devices for each of these are included in the text, but the reader is encouraged to obtain complete data sheets for such a device when the need arises to solve an interface problem.

Copious amounts of detailed hardware and software examples are provided covering signal amplification and filtering to condition the output from external sensors and make them logic compatible, D/A and A/D conversion, data transfer techniques including STD and IEEE-488 bus protocols, and parallel and serial I/O including the EIA-RS232 standard. Well recommended for anyone planning to communicate a home built microprocessor system, no matter how modest, with another computer or electronic peripherals including relays, motors, sensors and opto-isolators etc.

1990. 226 x 150mm. 200 pages, illustrated.

Order As WT14Q (MCP Interfacing) Price £10.95 NV



Automobile Electrical and Electronic Systems

A 'Haynes' Manual
by Tony Tranter

This book meets the need for a clear explanation of modern electronic equipment used in the car, and has been written with the co-operation of the major manufacturers. Few subjects can be developing more quickly than that of vehicle electrics, and this new manual covers every aspect of automotive electrics from the basics up to the forefront of vehicle technology at the time of writing. The book sets out to explain how electrical and electronic equipment works, while at the same time no prior knowledge is assumed on the reader who progresses logically to an understanding of the latest technology. Specific equipment and vehicles are referred to by way of illustration and the text is an ideal combination of theory and practice.

While up-to-date practice is the main theme, some older equipment and systems are included, for not only do they often lead in a logical fashion to present day technology, but are still present in millions of vehicles on the road. No prior knowledge is necessary and first principles are dealt with in the first chapter. All explanations are given in this way, for which there is no substitute, giving the reader a firm basic comprehension of electrical and electronic principles so as to be able to progress onto more advanced equipment. Topics include batteries, starting and charging systems, fuelling, ignition and combustion, engine management, lighting and instruments, electromagnetic interference, vehicle wiring, general fault diagnosis, test equipment, and includes latest developments in fuel injection, pollution control, engine and body electronics, and braking and anti-skid systems. Specific details of any particular type of vehicle are given only by way of illustration and example.

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An introduction to SINGLE CHIP MICROCOMPUTERS/CONTROLLERS

by Jeff Wright BSc (Hons)

Introduction

Everyone interested in electronics will be familiar with the term microprocessor and what it stands for – a computational circuit fabricated on a single piece of silicon. The rapid development of the microprocessor has quite literally changed the world in which we live in the last twenty years. Enormous leaps in performance have been achieved during this period so that current 'flagship' microprocessors like Motorola's 68040 and Intel's 80486 can perform tens of millions of instructions per second.

As with fast cars in the motoring world, these vastly powerful number crunchers grab all the limelight in the electronic press, and many reports are to be found when a new chip in this league is launched. However, the 'traditional' microprocessor is out-sold many times over by an offspring that is often overlooked by the electronic press and therefore will be unfamiliar to many readers. This offspring of the microprocessor is the Single Chip Microcomputer or 'Micro Controller Unit' (MCU). These ingenious devices are to be found in many of the modern consumer and automotive products that we use every day, but what exactly is a single chip microcomputer or microcontroller?

To answer this question we must first understand, or refresh our memories, of the elements of a conventional computer based around a microprocessor. Figure 1 shows a simplified block diagram of a typical computer system. As shown, a computer requires several other elements in addition to the Micro Processor Unit (or MPU): these are memory, clock/reset generator and input/output (I/O) devices. A brief description of these elements is given as follows:

Microprocessor

The microprocessor is basically an Arithmetic Logic device or Unit (ALU) that manipulates input data to produce a result. However, unlike a fixed logic circuit, like an adder for example, a microprocessor can manipulate the input data in a number of ways depending on the value of a *second* type of input to the microprocessor – the instruction. All microprocessors require a series of instructions to tell them what to do with the currently held data. A set of these instructions, designed to get the microprocessor to perform a series of tasks, is called a program. A microprocessor instruction is actually a binary number, but since binary numbers are cumbersome for a human to deal with, the actual value of an instruction is usually represented as an alphabetic word called a mnemonic. These mnemonics can be used by the programmer to write his program (called the source code) using an 'assembler', by which they are then converted to the basic binary instructions or machine code. This conversion can be done by hand using conversion tables, but this would be *very* time consuming, so most often another computer program, the assembler, is used for this task. This method of programming is called assembly language programming. Figure 2 shows a sample of a 6800 assembly language program listing that also shows the resulting assembled machine code on the left-hand side in hexadecimal form.

Collectively, all these valid binary instructions for a given microprocessor, and which are identified by mnemonics, are referred to as the processor's 'Instruction set'.

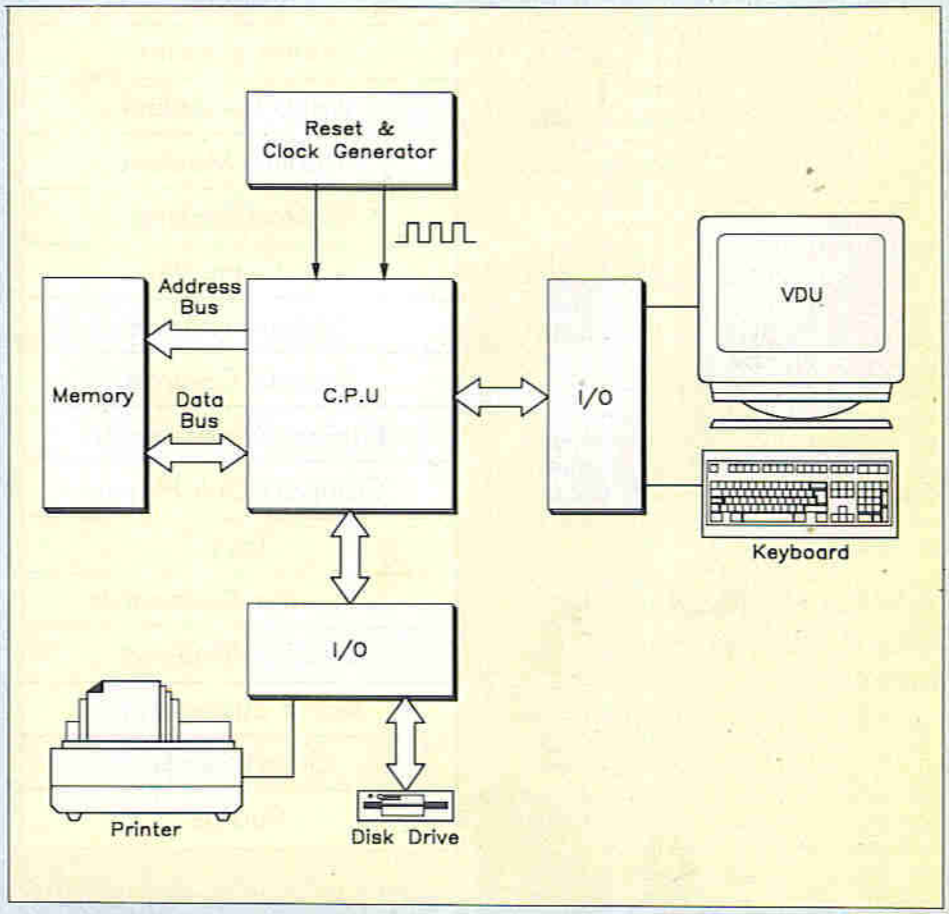


Figure 1. Block diagram of a typical computer.

Memory

Since a microprocessor can generally use only one instruction at a time, and a program can contain many thousands of instructions, somewhere else must be provided to store the instructions until the processor is ready for them – this is one function of memory. The type of memory used to hold the program of instructions for the microprocessor is generally ROM (Read Only Memory), so called because the data contained in the memory can only be read and cannot be altered. The contents of ROM are also retained after power is lost, i.e. the data is 'non-volatile'.

It is usually the case that a microprocessor also requires a memory area to store variables and intermediate results of a task that it is performing. For this purpose a second type of memory called RAM (Random Access Memory) is used. In RAM, data can be read or written to any location, however, the data is only temporary insofar that it is lost when power is removed. In some systems, data is preserved in RAM by back-up batteries when the main power source is lost. Single bytes of RAM can also be referred to as 'registers', and a microprocessor has its own special set of registers internally that are used when specific types of instructions are executed.

Clock and Reset Generator

A microprocessor is a synchronous device that requires a regular clock signal in order to operate correctly. Some means must also be available to start up the microprocessor from a known condition – this action is called resetting the processor. Generally some additional external circuitry is required to generate the processor clock from a quartz crystal, and to provide a means of activating the known reset condition of the processor for start-up.

Input/Output

A microprocessor or computer is of very little use to anyone if it cannot exchange information with external equipment. For this reason a microprocessor system requires blocks of hardware called I/O devices to allow it to 'talk' to the outside world. In a computer as most of us know it, these I/O devices would allow the microprocessor access to the keyboard, disks, serial ports, printer and VDU.

So What is a Single Chip Microcomputer/controller?

To get back to the original question, a Single Chip Micro Computer Unit (MCU for short) is simply a single circuit on a silicon chip that contains all the elements of a full computer system (processor, memory, clock, reset and I/O). The term microcomputer describes perfectly what these devices are but, since this name is sometimes applied to the personal computer, and the MCU is usually implemented in a control function, the name Single Chip Microcontroller or just microcontroller is more commonly used these days.

These single chip computers have found their way into numerous applications and, as the price falls with increasing manufacturing experience, they find more and more new applications – often displacing standard logic in previously 'dumb' (non-'intelligent') applications. Table 1 shows a selection of applications that currently use MCU's. The benefits of using an MCU in an application, as opposed to a lot of discrete logic or a traditional microprocessor system, are reduced circuit complexity and increased flexibility. The reduced circuit complexity leads to lower manufacturing costs, increased reliability and smaller product size. Increased flexibility can allow functional changes to be made by altering the software without having to change the printed circuit board. All these benefits are vitally important in today's highly competitive electronics industry, so it is not surprising that MCU's are big business (it is estimated that the yearly market for MCU's is 3000M units), and all the major semiconductor manufacturers have their own families of devices.

Different applications require different amounts of processor power (a toaster does not require the processing power of an engine management unit) and so MCU's are available with 4, 8, 16 and now 32-bit wide data busses. Currently the 4 and 8-bit devices are the biggest sellers by far, but it has been predicted that as prices continue to fall the 16-bit processors will migrate into some of the current 8-bit slots, and the 8-bit processors will in turn squeeze out

LINE NUMBER	ADDRESS	MACHINE CODE	LABEL	ASSEMBLY LANGUAGE (mnemonics)		COMMENTS
00100				NAM	ABS	
00110				OPT	M	
00120	0000			ORG	0	
00130	0000	0001	W	RMB 1		
00140	0001	0001	Y	RMB 1		
00150	0002	0001	Z	RMB 1		
00160	0500			ORG	$0500	
00170	0500	96 00		LDA A	W	
00180	0502	2A 01		BPL	Z1	IS W POSITIVE?
00190	0504	40		NEG A		W WAS NEG., MAKE POS.
00200	0505	D6 01	Z1	LDA B	Y	
00210	0507	2A 01		BPL	Z2	IS Y POSITIVE?
00220	0509	50		NEG B		Y WAS NEG., MAKE POS.
00230	050A	10	Z2	SBA		SUBTRACT Y FROM W
00240	050B	2E 01		BGT	Z3	IS Z POSITIVE?
00250	050D	4F		CLR A		RESULT WAS ZERO OR NEG.
00260	050E	97 02	Z3	STA A	Z	STORE ANSWER IN Z.
00270	0510	20 FE		BRA	*	
00280				MON		

Figure 2. An example of assembly language program source code with assembled output object code in columns 2, 3, 4 and 5.

Televisions
Microwave Ovens
Telephones
Anti Skid Braking
Pagers
Alarm Systems
Video Recorders
Washing Machine
Central Locking
Trip Computers
Fridge/Freezers
Remote Controls
Engine Management
Compact Disk Player
Toys
Computer Keyboards
Electric Windows
Active Suspension
Smart Cards
Radios

Table 1. A selection of typical microcontroller applications.

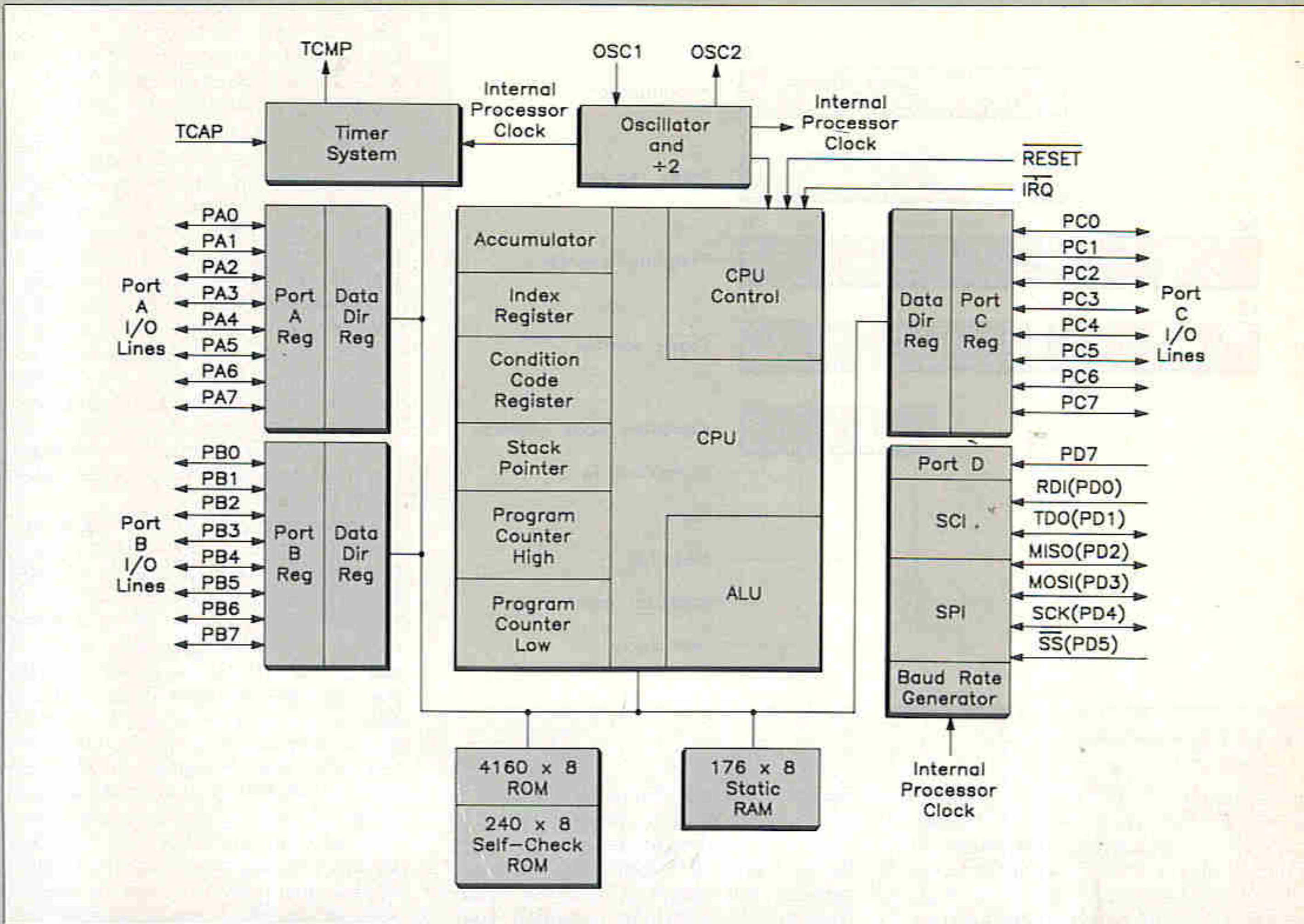


Figure 3. MC68HC05C4 Microcomputer block diagram.

Semiconductor Manufacturer	8 bit MCU family
Hitachi	HD6305
Intel	8048
Mitsubishi	M50747xx
Motorola	M6805/68HL05
National Semiconductor	COP 800
NEC	uCOM–78k
STM	ST6/8
Texas Instruments	TMS7000
Toshiba	68HL05

Table 2. Major 8-bit MCU families.

many of the 4-bit devices. Table 2 shows the major 8-bit MCU families that are used in many applications today.

A Typical MCU

Figure 3 shows a block diagram of a typical 8-bit microcontroller – Motorola's MC68HC05C4. This device has been chosen as an example as it contains most of the common features found on MCU's. A quick comparison of Figure 3 with Figure 1 shows the similarities between the 68HC05C4 and the conventional computer model. The device contains a Central Processing Unit (CPU), both RAM and ROM, a clock generator and I/O devices in the form of three 8-bit parallel ports, and a third 8-bit port that is shared with two serial communication systems. Features like timers and serial ports are often referred to as on-chip peripherals. To get a better understanding of how the parts of an MCU contribute to the end application, a detailed description of the features of the 68HC05C4 follows. These descriptions apply to almost all MCU's, and where a comparison is required the Texas Instruments TMS7000 is used.

CPU

The heart of the MCU is the 8-bit processor or CPU, where the program is executed. The CPU has access to, and control over, all the peripheral circuits via the address and data busses – shown on Figure 3 as a single line connecting all the modules to the CPU. The processor on the 68HC05C4 has a total of 62 instructions and can address up to 8K bytes of memory space. The CPU has five internal registers and these are illustrated in more detail in the programming model of Figure 4. The accumulator and index register are special registers used during the execution of certain types of instructions – the accumulator especially for arithmetic operations. The program counter, as its name suggests, contains the address of the next instruction in memory to be executed by the processor. The condition code register contains bits that can be tested by the program to see if certain conditions were met after an instruction was executed.

In most programs there will be groups of instructions that have to be

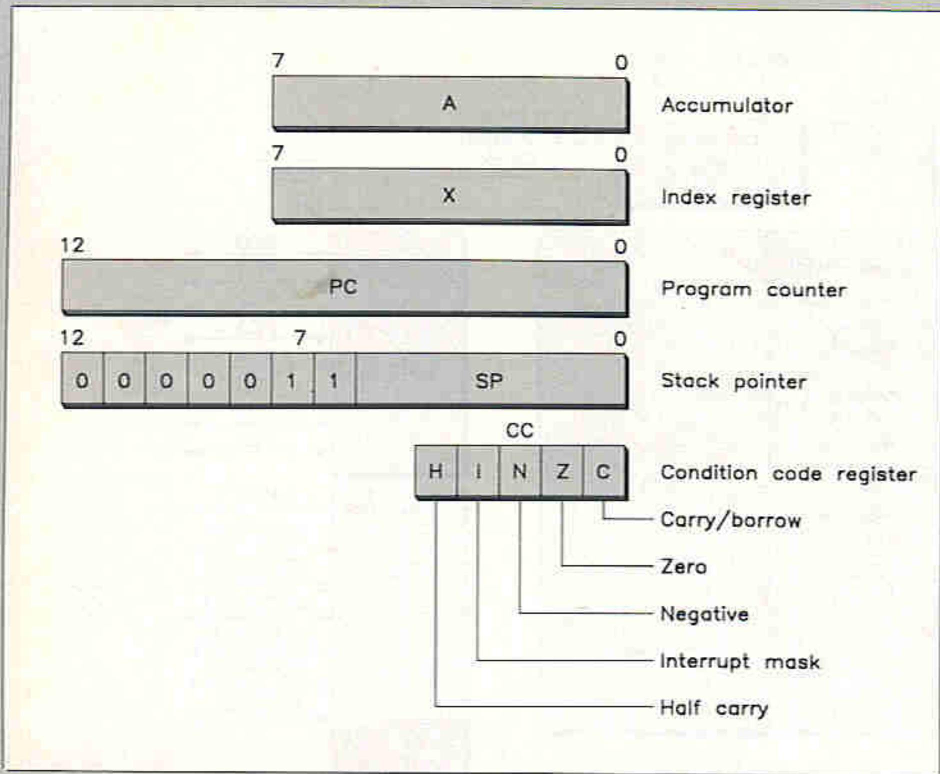


Figure 4. Programming model.

repeatedly used in several different places of the program. To save memory space these instructions are normally grouped into a little program called a subroutine. These subroutines can then be called up from anywhere in the main program. The problem is that when the processor has finished executing all the instructions in the subroutine, how does it know which part of the main program to return to? This becomes even more complicated as subroutines can be called from within another subroutine – this is called nesting. The problem is solved in the stack. The stack is an area of RAM that is used to store the current program position and other processor conditions before jumping into a subroutine or interrupt. The stack pointer as its name suggests, points to the current stack position so that the processor can successfully find its way back out of subroutines.

There is another input to the CPU that has not been mentioned so far – the Interrupt Request, or IRQ for short. When an IRQ is generated, the CPU will save its current state and program location on the stack before jumping to a special subroutine called the 'Interrupt Service Routine'. The important difference between an IRQ and a 'normal' subroutine call is that, with few exceptions, the IRQ is generated either by something else *outside* the MCU, or by one of the on-chip peripherals – i.e. it is a request on some part of the hardware for the MCU to go and do something rather than a request from within the software. This feature is vitally important in most MCU control applications where the processor must run a series of background activities but at the same time attend to certain tasks as soon as is required, e.g an interrupt may be used to alert the processor to the fact that a key has been pressed in applications such as a compact disk player. Unless the 'interrupt mask' bit in the condition code register is set, the processor will complete the execution of the current instruction, and then jump immediately into the relevant interrupt service routine. With most MCU's an interrupt can be generated from several different sources, and the source must either be identified by software or, as in the case of the 68HC05C4, a separate interrupt service routine is provided for each possible interrupt source.

MCU Memory

RAM and ROM have already been discussed in the introduction, and it can be seen from Figure 3 that the 68HC05C4 contains 4160 bytes of ROM available for program storage, 240 bytes of self-test ROM and 176 bytes of static RAM. With this being a CMOS processor, the static RAM allows the clock frequency to be reduced to zero without any loss of data, whereas for example 'dynamic RAM' would require a minimum clock frequency to be maintained to refresh the memory contents. The amount of memory available in MCU's varies enormously depending on the cost and performance requirements of the application. ROM sizes from 1 to 64K-bytes, and RAM sizes of 32 to 500 bytes are common for 8-bit MCU's.

One problem with MCU's is that the complex peripherals contained on chip make the devices very difficult to test for faults at the end of the manufacturing process. One way to alleviate this problem is to include a built in test program in the ROM of the device that can be used to supplement other factory tests. The 240 bytes of self-test ROM on the 68HC05C4 contain a test program for this purpose.

It is worth mentioning here that the nature of ROM (the program is permanently stored as part of the manufacturing process and cannot be changed) means that this type of MCU is normally limited to high volume applications (>10K units typically) where the cost of customised manufacture is justified. In order to bring the benefits of MCU's to lower volume applications, various solutions have been developed, and it is *these* devices that will be of most interest to the hobby electronics enthusiast who would like to start applying the power of MCU's to his projects.

Many MCU's with an on-board' OM also have a sister device where the ROM is replaced with Erasable Programmable Read Only Memory – EPROM. This memory can be programmed in a special programming mode (to gain access to the actual EPROM via the package pins) and can be erased at a later date if necessary by ultraviolet light. A newer technology, called Electrically Erasable Programmable Read Only Memory – EEPROM – is now also used for this purpose. These devices are often referred to as 'emulation parts', as they are actually used to emulate the function of the final production ROM devices while developing a new application.

An alternative solution is to produce an MCU with all the on-board features except the ROM, and provide instead an address and data bus that can be connected to an external ROM or EPROM. An example of this kind of MCU is Motorola's MC146805E2. Finally, another solution is to produce an MCU that has ROM on-board but which can be configured in a special way to use in addition external memory resources – an example of this type of device is the Texas Instruments TMS7000.

I/O

The Input/Output (I/O) ports are the peripherals of the MCU that allow it to access and control external hardware. A simplified equivalent logic diagram of part of one of the 8-bit I/O ports is shown in Figure 5. The port is basically made up of two 8-bit registers – the data register and data-direction register. The later determines on a bit by bit basis whether the pins will be configured as inputs or outputs and the former contains the data that will be presented to the pin if it is programmed as an output. The ports on the 68HC05 are referred to as 'memory mapped', as the port control registers are present in the normal memory area of the MCU and can therefore be manipulated by the full instruction set. This gives a significant advantage over some other MCU architectures, where the ports can only be manipulated by a limited set of special instructions. The reset condition of the MCU configures all the I/O ports as input so that damage will not be done to external hardware before the program has had a chance to configure the ports as required! Ports are normally capable of delivering a few milli-amps to external hardware, but many MCU's have one or more special ports with uprated current drive so that they can directly interface to LED's and high power transistors. When designing an application for an MCU it is important to stay within the manufacturer's specifications for port loading and voltages, otherwise damage could result. It is also recommended as good practice to configure unused ports as inputs and tie them safely to V_{DD} or V_{SS} via a resistor.

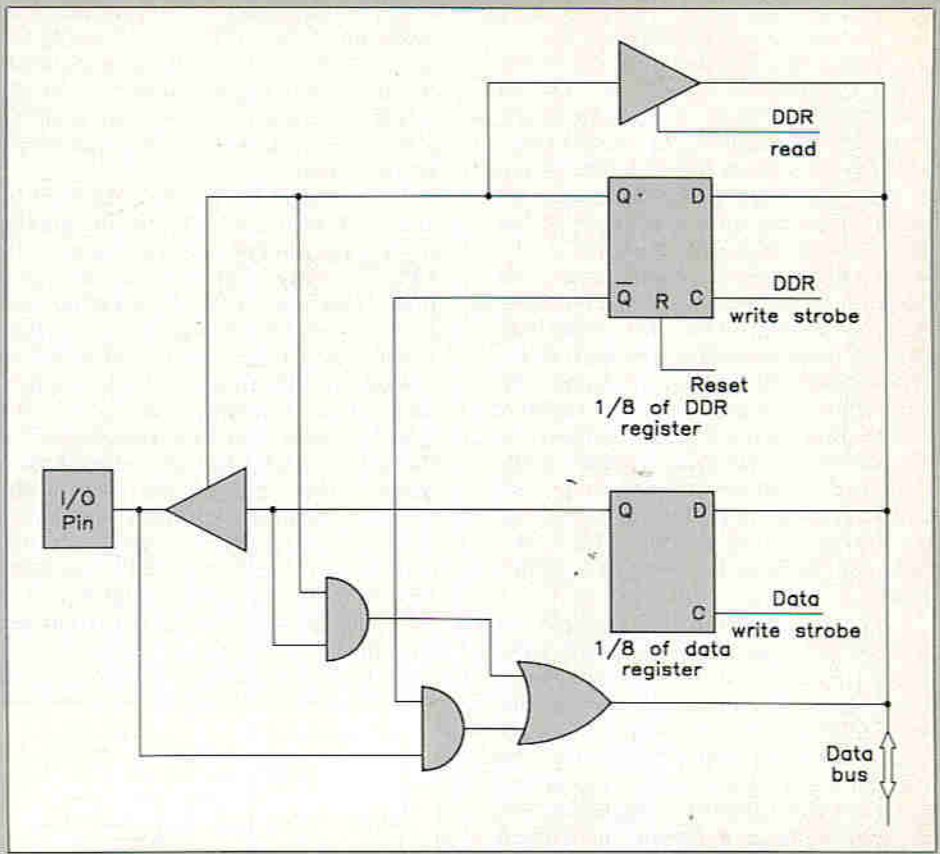


Figure 5. Simplified logic of an input/output (I/O) pin.

Timer

The Timer is one of the most powerful elements of an MCU and can often be the deciding factor when choosing a device for an application. Why does an MCU require a timer? It has its own clock internally so it could use that to measure time. Although the previous statement is true, if the processor spent its time counting in a software loop it would be entirely tied up and unable to continue with its other tasks. So the reason for providing one or more timers on an MCU is to allow timing tasks to be carried out with none or very little CPU intervention. A basic timer can be thought of as a counter that can signal to the CPU (often through an IRQ) that it has over or underflowed. Applications that require time to be measured are called 'real-time applications', and they range in complexity from washing machine controllers to high performance engine management systems. Obviously, the latter requires much more accurate timing than the former and so a wide range of timer complexities are available on MCU's to suit a variety of applications.

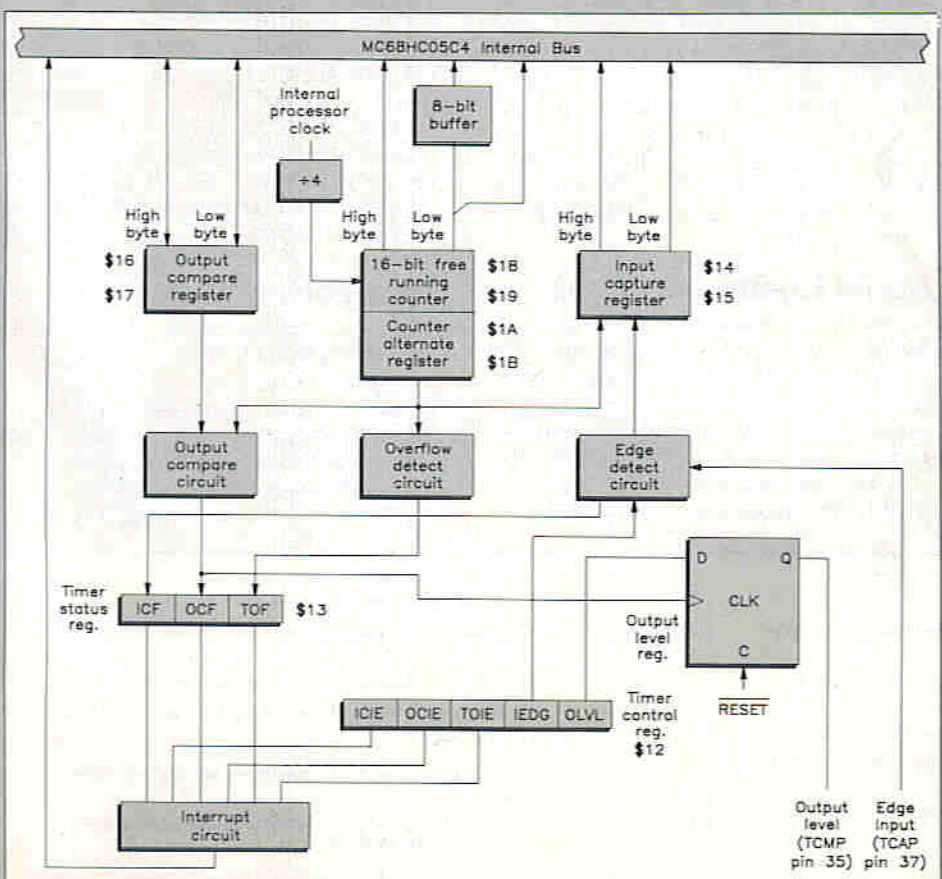


Figure 6. Programmable timer block diagram.

The timer on the 68HC05C4, shown in Figure 6, is of medium complexity and demonstrates most of the principals involved. The heart of this timer is the 16-bit free-running counter that is incremented every four processor clocks by the preceding pre-scaler. This counter can, if desired, generate an IRQ to tell the CPU that it has overflowed. The term 'free-running' is used to emphasise the fact that once started, the counter cannot be reset or reloaded by software, unlike some other timer structures where the CPU has full control. The idea of the free running timer may seem strange at first, but its advantages become clear if an application is considered where several timing tasks must be carried out simultaneously: say for example that you need to produce an output waveform of varying period (dependent on some internal control algorithm) while at the same time measuring the period and frequency of an incoming signal – see Figure 7. If the CPU loaded the timer with the period of the desired output and then went away to do something else, how would it measure the period of the incoming signal? To do this the CPU would have to keep track of the number of part and full cycles of the timer and use this in conjunction with the current period of the output waveform to calculate the period of the incoming signal. This would use a fair degree of CPU processing time or overhead. A free running timer overcomes these 'multitasking' problems with the help of a couple of peripheral functions.

These two functions are called the 'Input Capture' or 'Latch' and 'Output Compare' or 'Match'. In the case of the input capture function, the current value of the timer counter is latched and stored in a register when a certain predefined transition occurs on a special pin of the MCU (called TCAP on the 68HC05C4). When this capture takes place, an interrupt can be generated and the CPU can read the value of the timer at the time of the capture whenever it is convenient. With the output compare function, the CPU stores a value in a special register. This register is compared by hardware to the current counter value on every timer clock cycle, and when the 2 values are equal a predetermined level is written out to an output pin of the MCU. An interrupt can also be generated at this point.

Now to go back to the example, to generate the output waveform the CPU would simply read the current timer value, add on the desired period and write this value to the output compare register. The CPU can then go and get on with the rest of its work until the compare matches, whereupon the output pin will be toggled and the processor interrupted so that it can set up the timer for the next period. In a similar way the CPU can store subsequent timer values when the input captures occur, and by subtracting one from the other it can easily obtain the period of the signal applied to the timer capture pin. In this way, having an independent timer with capture and compare functions allows simultaneous waveform generation and measurement with very little CPU overhead. The real advantage of this type of timer structure is that a single timer can have several input capture and output compare functions allowing multi signal processing. It is this technique that is used in automotive ignition control to capture the timing signal from the crankshaft and to generate the ignition firing pulses.

If the CPU itself is involved in a time critical task then it would not be a good idea to interrupt it from the timer. For this reason the various interrupts from a timer system can usually be masked, and status bits that can be tested by the software when it is convenient are used instead. These bits are shown in the timer status register of Figure 6. Some timers have a choice of clock source including an input pin of the MCU, thus allowing the timer to be incremented by an external signal. In this mode a timer is actually called a counter as it is in effect counting external events that can be completely asynchronous.

Many 8-bit MCU's like the 68HC05 and TMS7000 have 16-bit or greater timers, and this presents a problem as the CPU can only read 8-bits of data at a time. If the timer value changed between reading the two halves then a wrong result would be obtained that could be potentially disastrous in some applications. This problem is solved by the 'pipeline latch' that captures one half of the timer value when the other half is read by the CPU. In the case of the 68HC05, the most significant byte is read by the CPU and the least significant byte is latched. Then when the CPU reads the LSB it is the value in the latch that is returned. This operation is carried out entirely automatically.

The timer system, therefore, is a

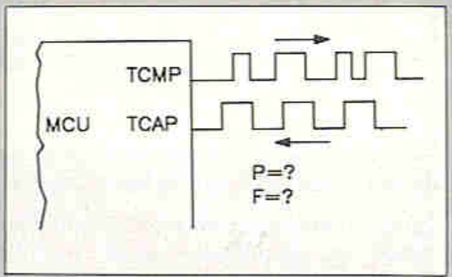


Figure 7. Example timer signals.

very powerful part of an MCU and in many applications the availability of timer features will take precedence over processor ability when choosing the right MCU for the job. This is because a timer with features well suited to the application can easily make up for a lack of processing power when compared to an MCU with a powerful CPU that will have to spend some of its time making up for timer deficiencies.

Serial Communications

Serial communications on an MCU greatly increase its flexibility and I/O capabilities, and are used for two main purposes – to allow communication to other MCU's or computers and to facilitate the use of external peripherals.

The distance over which the communication must take place and the surrounding environment must be taken into consideration when selecting a serial protocol. Communication to a peripheral device or another MCU mounted on the same PCB can use a simple high speed protocol. However when transmitting over a long distance or through a bad environment, data corruption due to noise can become a problem and so a slower protocol with some error detection is desirable. The 68HC05C4 contains two independent serial subsystems to handle both of these requirements. The first, called the Serial Peripheral Interface (SPI), is a high speed synchronous (up to 1M-bit/sec.) system that is designed to communicate to peripheral devices such as Analogue/Digital converters or LCD display drivers, or to one or more other MCU's. Connecting several MCU's together to form a sort of distributed processing system can sometimes be more cost effective and flexible than using a more complex single controller. The second type of protocol is handled by the Serial Communications Interface (SCI), which provides asynchronous communication with selectable baud rates and advanced error detection capabilities. The SCI provides an excellent means of communicating with a host computer or terminal using the RS232 protocol, thus allowing an MCU program to be controlled interactively by a user. Some MCU's combine both these communication types in a single system that can then perform one or the other at any one time – the TMS7000 series is an example of this approach.

Further Features

The above sections have explained the operation of the main functional blocks that are shared by almost all micro-controllers. There are, however, other features that are commonly found on many but not all MCU's – these include low power modes and additional on-chip peripherals.

Low Power Modes

If a microcontroller has been designed in a static CMOS technology then it is possible to stop the clock to the device without corrupting any of the internal states of the processor and subsystems. Static CMOS only uses significant amounts of current when it is switching so that removing the clock

MCU function	Explanation/Application
VFD ports	Special high voltage ports for driving vacuum fluorescent displays in many products.
LCD ports	As above but for LCD displays. Usually includes multiplexing for several digits/characters.
A/D	Analogue to Digital converter used to read a variety of sensors etc.
PWM or D/A	A Pulse Width Modulated output that can be smoothed to provide a programmable analogue voltage.
PLL	Phase Locked Loop. Used in tuner applications such as television or radio.
EEPROM in addition to ROM	Can be used for calibration purposes or as a non-volatile data store.
Watchdog	A special type of timer that is used to guard against software runaway.
Wake-up port	Used in large keyboards to allow any pressed key to generate an IRQ.
DTMF	Dual Tone Multi Frequency generator, used in telephone applications.
RTC	Real Time Clock, a special timer designed to make counting real time easier.
OSD	On Screen Display. A character generator for showing status such as volume level on the TV screen.

Table 3. Additional MCU features.

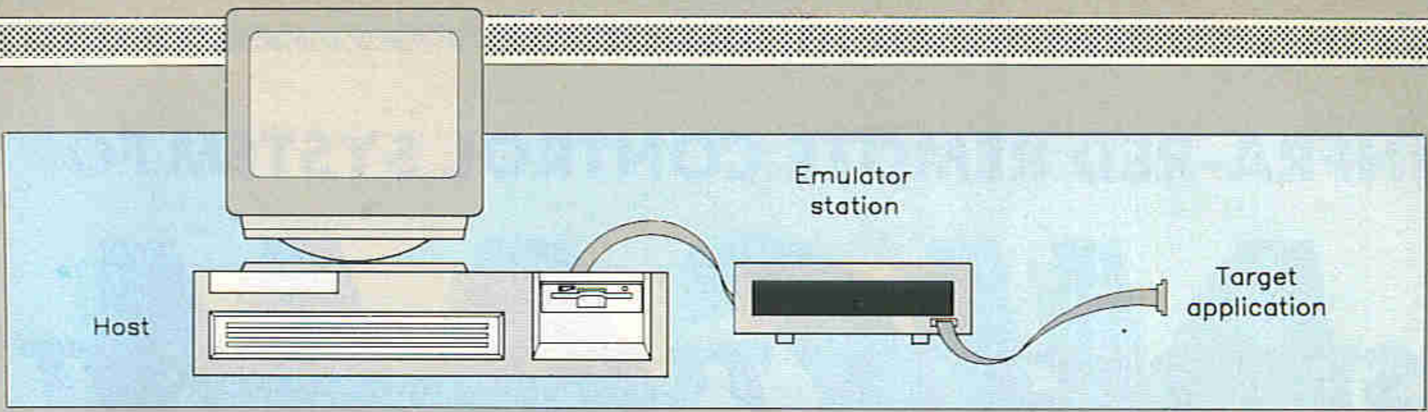


Figure 8. Development system set-up.

dramatically reduces the power consumption of the device from say a few milli-amps during normal running to a few micro-amps in this 'suspended' state. This feature of CMOS microcontrollers is vitally important for many battery powered applications, such as remote controls and pagers, where battery life must be extended to a maximum. Other applications where power consumption is very important include telecom, where there are strict limits to the amount of current that can be taken from the telephone line, and automotive applications such as alarms that must be powered up when the engine is not running.

Most CMOS microcontrollers have two low power modes that can be entered via a special software instruction. Once in the low power mode the device is reactivated by an interrupt or reset. The first low power mode is commonly called 'STOP mode' and is the case described above – i.e. the clock is removed from all the functional blocks of the MCU and all activity stops. The processor can exit this mode when a signal is applied to an external interrupt pin or the reset pin. This feature could be used to save power while the processor is waiting for a key to be pressed to wake it up. The second type of low power mode (often called 'WAIT mode') removes the power from most but not all of the functional blocks. Typically the clock will be removed from everything except the timer and perhaps the serial interface. An interrupt from either of these two subsystems or an external signal can then be used to wake-up the processor. Power consumption in this mode is not as low as STOP mode but will still be typically a factor of 10 or more less than normal run mode. This mode can be used to periodically (via the timer) wake the MCU up from a low power state to perform a series of tasks and then go back to 'sleep' again.

Additional Peripherals

As the market for MCU's has grown rapidly, so has the demand of customers to integrate more peripheral functions on-board the MCU in order to further reduce their application chip count and therefore cost. This trend has lead to many MCU's having additional features over those described previously, resulting in a confusing array of MCU's on offer to the application designer – there are over 50 derivatives of the 68HC05 family alone! Table 3 shows a selection of these additional features and their uses. Some of the most powerful features are the analogue functions of A/D and D/A. The analogue to digital converter (A/D) allows the MCU to read and manipulate values from a wide range of sensors such as thermistors and pressure sensors, and to monitor things like the current being taken by a motor. The digital to analogue converter (D/A) is often implemented as a pulse width modulator (PWM) with smoothing external to the MCU to produce an analogue voltage. This feature can therefore be used to control a wide range of external analogue circuitry. As the design cycle time and cost of developing a new MCU fall, some MCU manufacturers have been able to offer a new solution to their high volume customers – the customer specific microcontroller where the on-board peripherals are tailored to exactly meet the application requirements.

How an Application is Developed

Finally, to end this introduction to microcontrollers, a short explanation of how an application based on an MCU is developed follows:

After the functionality of the application has been defined, the first step is obviously to pick the correct MCU for the job. Several factors must be taken into account when making this choice, including processor power, peripheral features, and hardware requirements such as power consumption and cost trade-offs of one solution versus another.

After this choice has been made, the required hardware around the MCU and the software for the device will be developed in parallel. As mentioned previously, the software is usually written in assembly language, however, latterly high level languages such as 'C' are becoming more popular as they are processor independent and therefore allow software modules written for one application to be used on another that is using an entirely different MCU. It's all very well developing all this software and hardware, but how do you check it out before giving your software to the semiconductor manufacturer to make several thousand ROMed devices?

The solution to this "debugging" of the application is the development system using the previously mentioned 'emulation parts' (erasable programmable MCU's). Figure 8 shows a diagram representing the set up of a development system for debugging an application. The system consists of a host computer, often a PC, the development station or emulator and the target connector that plugs into the application hardware in the socket that is intended for the MCU. Various complexities of emulators are available depending on the debug facilities that are required, but they can all perform the basic functions required. The emulator contains an MCU similar or the same as the one that will be used in the application, external RAM that replaces the internal ROM of the MCU and some special control circuitry. The software that is to be tested is 'downloaded' into the emulation RAM where it runs under full control of the host computer. This host interface allows the user to start and stop the application software at any point and examine the internal conditions of the MCU. He can also make changes on the fly to the emulation memory to try out fixes to errors that have been detected. The target connector allows the software to run in the application just like the final MCU and so hardware faults can also be identified.

Once the designer is happy with his software on the development system, he will usually program several EPROM version MCU's and use these in field trials to find any final bugs. With a small volume application the development will stop at this point, and further EPROM or ROMless parts will be used for production. For high volume applications, the designer will give his software to the MCU manufacturer, who will process it into a mask layer that is used during the manufacture of the MCU's to form the ROM contents. If no mistakes have been made in the development phase then fully operational MCU's containing the customer's software will be delivered to him a few weeks later.

Summary

This introduction has explained the basic operations of the various parts that go to make up a microcontroller, and hopefully has made the reader aware (perhaps for the first time) of just how powerful these relatively inexpensive devices (typically £1 to £10 in volume) can be for every day control applications. In a future issue an explanation of how these features can be used from a selection of the applications of Table 1 will be presented.

INFRA-RED REMOTE CONTROL SYSTEM FOR NICAM STEREO TV TUNER UNIT

by C.S. Barlow

Features
- ★ Hand-held transmitter
- ★ Long battery life
- ★ 22 Keyboard commands
- ★ Easy to install receiver module
- ★ Low power consumption
- ★ 4·5 metre range

Specification of Prototype

Infra-Red Transmitter

Commands:	TV channel 1 to 16 TV channel −/+ Volume −/+ Sound mute On/Off Standby On/Off
Transmission mode:	Flash
Transmit source:	Two high power infra-red emitting diodes
Peak wavelength:	940nm
Clock frequency:	455kHz
Power supply:	Two AA size alkaline cells
DC voltage:	3V
Standby current:	10nA
Transmit current:	Average 1·65mA, peak 1·1A

Infra-Red Receiver

Receive detector:	High speed photodiode
Peak spectral response:	950nm
Effective range:	4·5m
Receiver gain:	70dB
Data output pulses:	Negative going
DC power supply input:	+5V at 1mA

Stereo Volume Control

Frequency response:	5Hz to 150kHz −3dB
Output level:	1V RMS into 1kΩ
Gain:	0dB
Tracking:	0·3dB
Signal to noise:	68dB
Distortion:	0·2% THD
DC Power supply input:	+12V at 16mA

Introduction

The IR (infra-red) remote control unit has been designed for use with the completed Maplin NICAM television tuner system which is comprised from the following kits:

NICAM decoder (stock code LP02C), see December '89 – January '90 magazine.

NICAM tuner (stock code LP09K), see February – March '90.

NICAM accessories part one, see June – July '90.

NICAM accessories part two (stock code LP18U), see August – September '90.

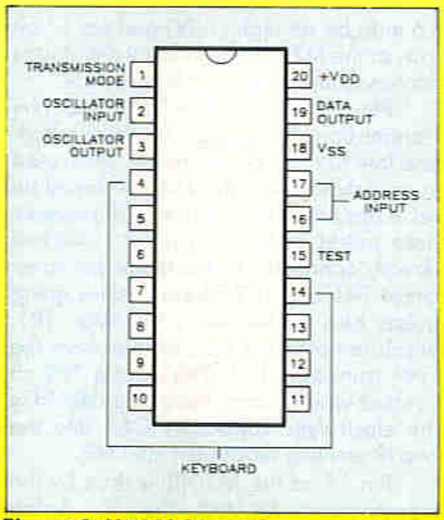


Figure 1. M708L Pin out.

In addition, a super NICAM kit is available containing all three kits in one (stock code LP19V).

After the tuner is up and running it is relatively easy to add IR remote control to the system. This is because all the decoding circuits are already present in the M491B voltage synthesis tuning chip, which is located on the display PCB. The IR detector is also on this board and a 12-way PCB latch plug connects the IR receiver into the tuner system. Only a small amount of additional wiring is required to complete this installation. Testing and alignment of the IR receiver is straightforward requiring only simple DC measuring equipment.

The IR transmitter uses a special IC developed in conjunction with the M491B and requires few additional components to produce the correct IR transmitted data. The completed PCB assembly is designed to fit inside a custom made slime-line hand-held case which has a battery compartment, rubber keypad and IR transparent window.

IR Transmitter Circuit Description

The main active component in the transmitter is a M708L IC and its pin out is shown in Figure 1, a full listing of its absolute and recommended operating conditions is given in Figure 2. The operation of this IC can be simplified into separate procedures as depicted by the block diagram in Figure 3.

Referring to Figure 4, the following description illustrates circuit operation.

ABSOLUTE MAXIMUM RATINGS

Parameter	Value	Unit
Supply voltage	−0.3 to 5.5	V
Input voltage	−0.3 to V_{DD} +0.3	V
IR output current (t<50μs)	10	mA
Operating temperature	0 to 70	°C
Total package power dissipation	200	mW
Storage temperature	−55 to 125	°C

Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

Parameter	Limit	Unit
Supply voltage	2.2 to 5	V
Input voltage	0 to V_{DD}	
IR output current (t<50μs)	max 2.5	mA
Reference frequency	445 to 510	kHz
Operating temperature	0 to 70	°C
Serial resistance of a closed key contact	max 2.5	KΩ
Parallel resistance of open key contact	min 2.2	MΩ
Serial resistance of the ceramic resonator	max 20	Ω

STATIC ELECTRICAL CHARACTERISTICS (T_{amb}=25°C)

Parameter	Pins	Test Conditions		Values Min	Typ	Max	UNIT
Supply voltage		V_{DD}=5V IR output open	Stand–by	–	3	10	μA
			Operating (one key closed)	–	4	7	mA
H State IR output current		V_{DD}=3V	V_{OH}=2V	−1	−2	–	mA
		V_{DD}=2.2V	V_{OH}=1V	−0.3	−0.5	–	
L State IR output current		V_{DD}=3V	V_{OL}=1V	1	2	–	mA
		V_{DD}=2.2V	V_{OL}=1V	0.3	0.5	–	
Input high current	Address selection input	V_{DD}=3V V_{IL} =3V (oscillator running)		–	–	150	μA
Input leakage current	Trans. mode Test pin	V_{DD}=3V V_{IN} =0 to 3V		–	–	1	μA

Figure 2. M708L Electrical characteristics.

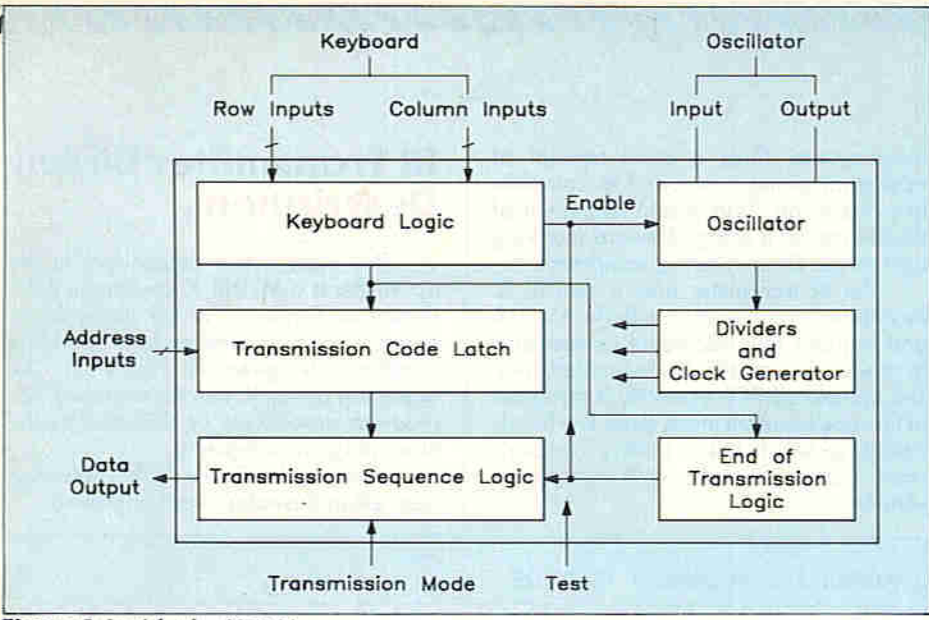


Figure 3. Inside the M708L.

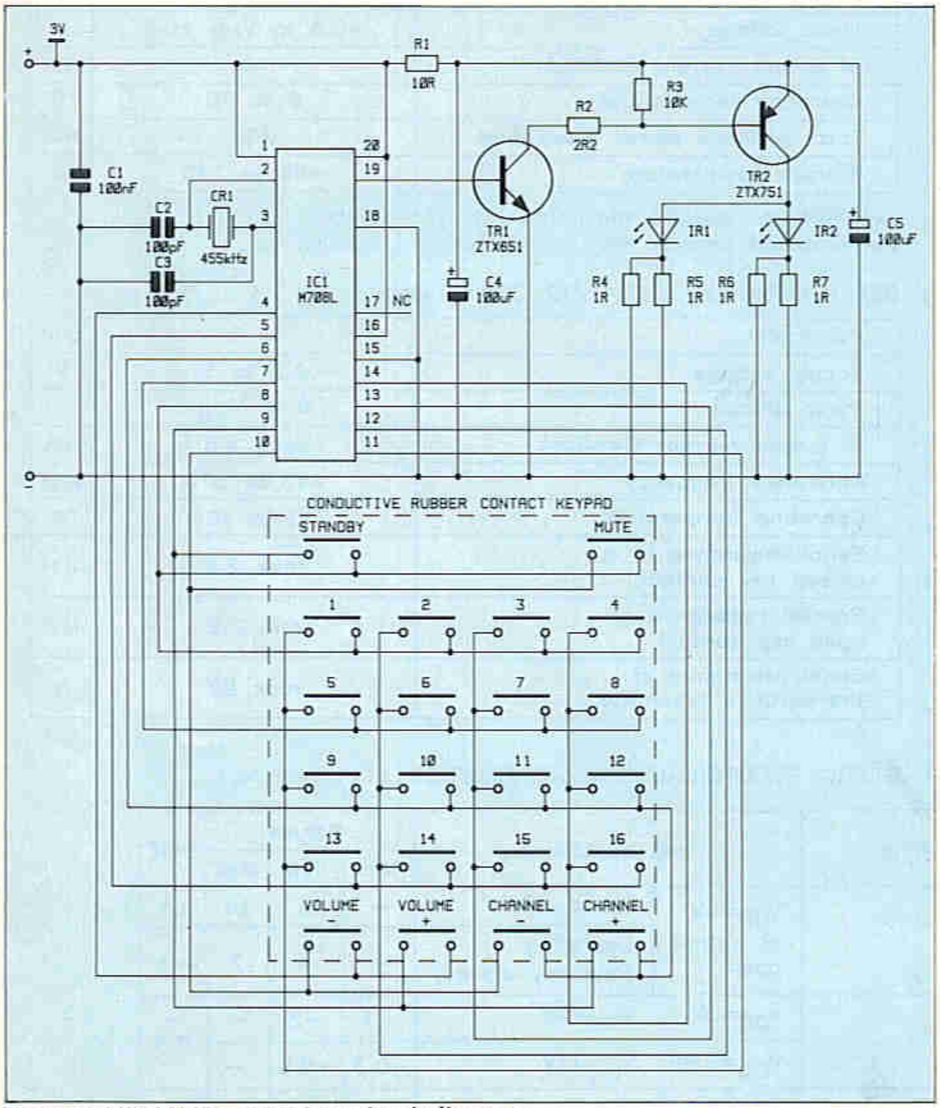


Figure 4. NICAM IR transmitter circuit diagram.

The DC power for the transmitter is provided by two AA batteries connected in series to give three volts. This supply is high frequency decoupled by a 100nF ceramic disc capacitor, C1, before connecting to pins 18 and 20 of the M708L IC1.

Synchronisation between the transmitter and receive decoder (M491B) is necessary to obtain maximum reliability. The frequency of the clock oscillator in the decoder is set by a 455kHz ceramic resonator (stock code UL61R) and this component, CR1, is also used to set the timing of the transmitted data pulses.

The keyboard code command is selected by connecting together one of the row input pins, 4 to 8, and one of the column input pins, 9 to 14, see Figure 5. As can be seen 30 command codes can be generated by the IC but only 22 have been implemented to control the NICAM tuner. A 22 way conductive rubber contact keypad is used to make each connection, which must be closed for a minimum of 25ms to pass its antibounce test before the command is transmitted. The command information is repeatedly sent out at intervals of approximately 108ms as long as the key button remains operated. Double and multiple contact operations are not accepted. When the key is released and after a pause of 18ms the end of transmission code is sent and the IC returns to its low current stand-by mode.

Each time a command is transmitted an address code is also sent which must match the one in the decoder IC (M491B). The two address inputs are on pins 16 and 17 which provide four possible address codes. When using a M491B decoder pin 16 must be set high (+3V) and pin 17 set low, as the M708L has internal pull-downs no connection to pin 17 is necessary.

Pin 1 on the M708L sets the transmission mode, high (+3V) for flash and low (0V) for carrier mode, when used in conjunction with the M491B it must be set to operate in its flash mode. The transmit data pulses appear on pin 19 which is directly connected to the IR current driver circuit TR1 and TR2. These positive going pulses bias on the NPN transistor, TR1, which removes the hold off bias from the PNP transistor, TR2. This causes TR2 to conduct which dumps the charge stored in the electrolytic capacitors C4,5 into the two IR emitting diodes IR1 and IR2.

Pin 15 of the M708L is used by the manufacturer to test the IC during production and must be connected to the 0V ground to ensure normal operation.

IR Transmitter Assembly

The PCB is a double-sided, plated-through hole type, chosen for maximum electrical reliability and mechanical stability. However, removal of a misplaced component is quite difficult with this kind of board so please double-check each component type, value and its polarity where appropriate, before soldering! The PCB has a printed legend to assist you in correctly positioning each item, see Figure 6.

The sequence in which the components are fitted is not critical. However, the following instructions will be of use in making these tasks as straightforward as possible. For general information on soldering and assembly techniques please refer to the 'Constructors' Guide' included in the Maplin kit.

Because of the restricted space inside the transmitter case several of the taller components must be pushed over so they lay flat on the surface of the PCB. The following components have had their outlines printed on the legend to reflect this:

455kHz Ceramic resonator	CR1
100nF Ceramic disc capacitor	C1
100pF Ceramic capacitors	C2 and C3
100μF Electrolytic capacitors	C4 and C5
ZTX651, ZTX751 Transistors	TR1 and TR2
IR emitter diodes	IR1 and IR2

M708L Command No.	Keyboard PIN No.											M491B Function (NICAM Tuner display PCB)	
	8	7	6	5	4	9	10	11	12	13	14		
0	End of Transmission												
1	X					X						Standby On/Off	
2	X						X					Mute On/Off	
3	X							X				Memory 1	
4	X								X			Memory 2	
5	X									X		Memory 3	
6	X										X	Memory 4	
7													
8													
9		X						X				Memory 5	
10		X							X			Memory 6	
11		X								X		Memory 7	
12		X									X	Memory 8	
13			X			X						Memory Up	
14			X				X					Memory Down	
15			X					X				Memory 9	
16			X						X			Memory 10	
17			X							X		Memory 11	
18			X								X	Memory 12	
19													
20													
21				X				X				Memory 13	
22				X					X			Memory 14	
23				X						X		Memory 15	
24				X							X	Memory 16	
25					X	X						Volume Up	Mute
26					X		X					Volume Down	Off
27													
28													
29													
30													

Figure 5. NICAM IR remote control commands.

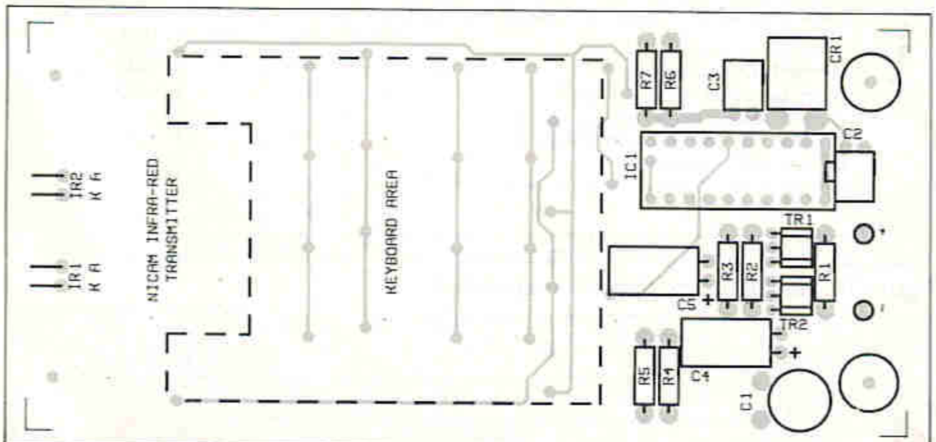


Figure 6. NICAM IR transmitter PCB legend.

When installing the two transistors ensure that their rounded edges are facing away from the surface of the PCB. There is insufficient headroom for the M708L to be fitted into an IC socket, so please make absolutely certain that the notch on the IC matches the block on the legend. Finally, when mounting the IR diodes ensure that the shorter cathode lead is located at the hole marked 'K' and its flat base is on the front edge of the PCB, see Figure 7.

This completes the assembly of the PCB and you should now check your work very carefully making sure that all the solder joints are sound. It is also very important that the solder side of the circuit board doesn't have any trimmed component leads standing proud by more than 2mm, as this may result in a short circuit.

Next fit the completed PCB assembly into the transmitter case as follows:

1. Position the rubber contact keypad through the top half of the case.
2. Locate the PCB over the keypad and push into place.
3. Use two short lengths of insulated wire to connect the battery terminals to the PCB.
4. Position the transparent window over the IR diodes.
5. Secure the bottom half of the case using the four countersunk screws.
6. Remove the battery cover.

IR Transmitter Testing

All the DC tests are to be made using a multimeter and two AA batteries. The readings were taken from the prototype using a digital multimeter, some of the readings you obtain may vary slightly depending upon the type of meter employed.

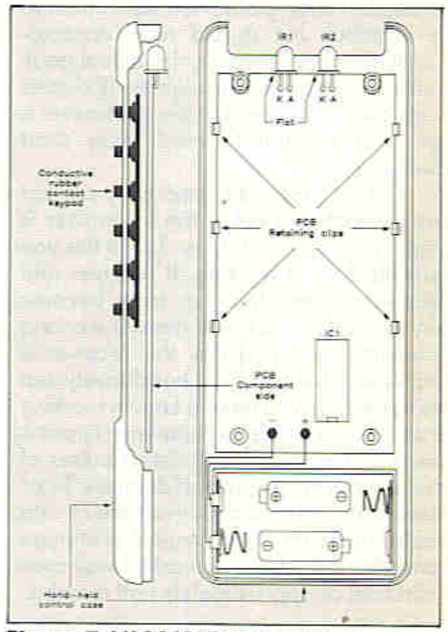


Figure 7. NICAM IR transmitter assembly.

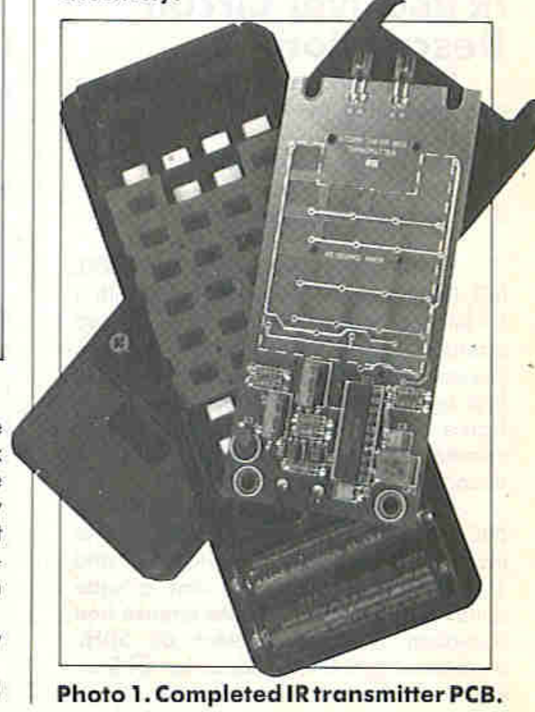


Photo 1. Completed IR transmitter PCB.

The first test is to ensure that there are no short circuits before you install the batteries. Set your meter to read kΩ on its 20kΩ resistance range and connect the test probes to the positive and negative battery terminals. With the probes either way round a reading greater than 4kΩ should be obtained.

Following the polarity markings moulded inside the battery compartment install the two AA batteries. Next monitor the supply current, set your meter to read DC μA and place it in series with the battery supply. Ensuring that none of the rubber keys are pushed in, observe the current reading which should be approximately 10nA, some multimeters may not possess sufficient resolution to read this extremely low standby current. Now set the meter to read DC mA and push in one of the transmitter command keys. Because of the pulsed current fed to the two IR diodes the reading obtained will appear to be unstable, but should read approximately 1·6mA. However, the actual peak current being pulsed through the IR diodes is just over one amp, but the multimeter is not quick enough to read these short duration pulses.

The DC tests on their own do not prove conclusively that the transmitter is sending out any IR energy. To do this you must build up a working IR receiver and decoder system. This can soon become very confusing since you need a working transmitter to prove that the receiver is functioning correctly. To conclusively test the transmitter you need a known working IR detector, a simple experimental circuit is shown in Figure 8. It will detect pulses of energy from the majority of domestic TV or video hand sets and convert them into visible red light. The Maplin prototype transmitter and detector worked well over a distance of approximately half a metre.

IR Receiver Circuit Description

The IR receiver module contains three separate circuits, see Figure 12.

1. IR receiver IC3.
2. DC controlled stereo amplifier IC1 and IC2.
3. DC transistor switching TR1 to TR4.

1. The IR receiver uses a TBA2800, IC3, its pin out is shown in Figure 9 with a full listing of its absolute and recommended operating conditions given in Figure 10. The operation of this IC can be simplified in four separate procedures as depicted in Figure 11. All stages are powered from a common +5V supply rail on pin 3 which is decoupled by C19 and C20.

A reverse biased photodiode on the NICAM display board is connected to the input of the first amplifier (1) via pins 9 and 10 of SK1. This amplifier has a wide dynamic range to ensure interference free operation at high ambient or 50Hz modulated light levels. Capacitor C15 on pin two influences the response of the

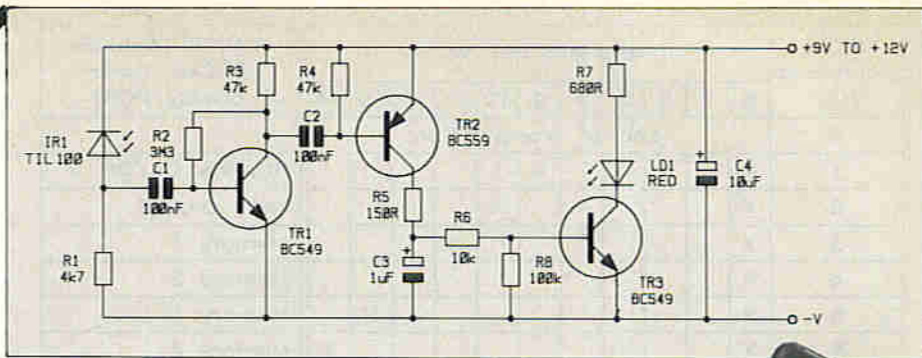


Figure 8. Experimental IR detector.

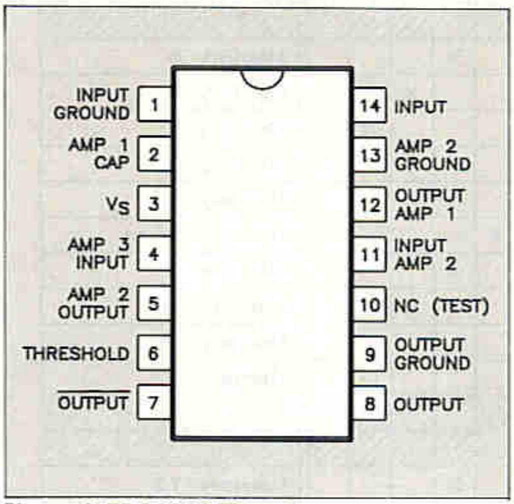


Figure 9. TBA2800 Pin out.

Photo 2. Boxed IR transmitter.

Absolute Maximum Ratings

	Value	Unit
Supply Voltage	6	V
Ambient Operating Temperature Range	−20 to +65	°C
Storage Temperature Range	−30 to +125	°C

Recommended Operating Conditions

	Min.	Typ.	Max.	Unit
Supply Voltage	4.5	5	5.5	V

Characteristics at V_S = 5V, T_A = 25°C

	Min.	Typ.	Max.	Unit
Current Consumption	–	1	2	mA
Gain between Pins 14 & 7	70	–	–	dB
Output Resistance Pins 7 & 8, formed by the pull-up resistor of an NPN transistor	–	20	–	kΩ
Output Low Voltage Pins 7 & 8 at I_{OL} = 1.6mA	–	0.4	0.8	V

Figure 10. TBA2800 Electrical characteristics.

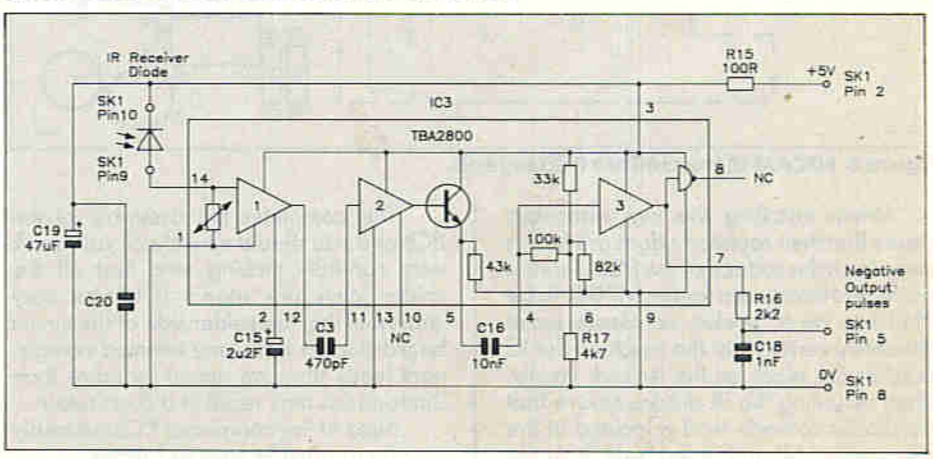


Figure 11. Inside the TBA2800.

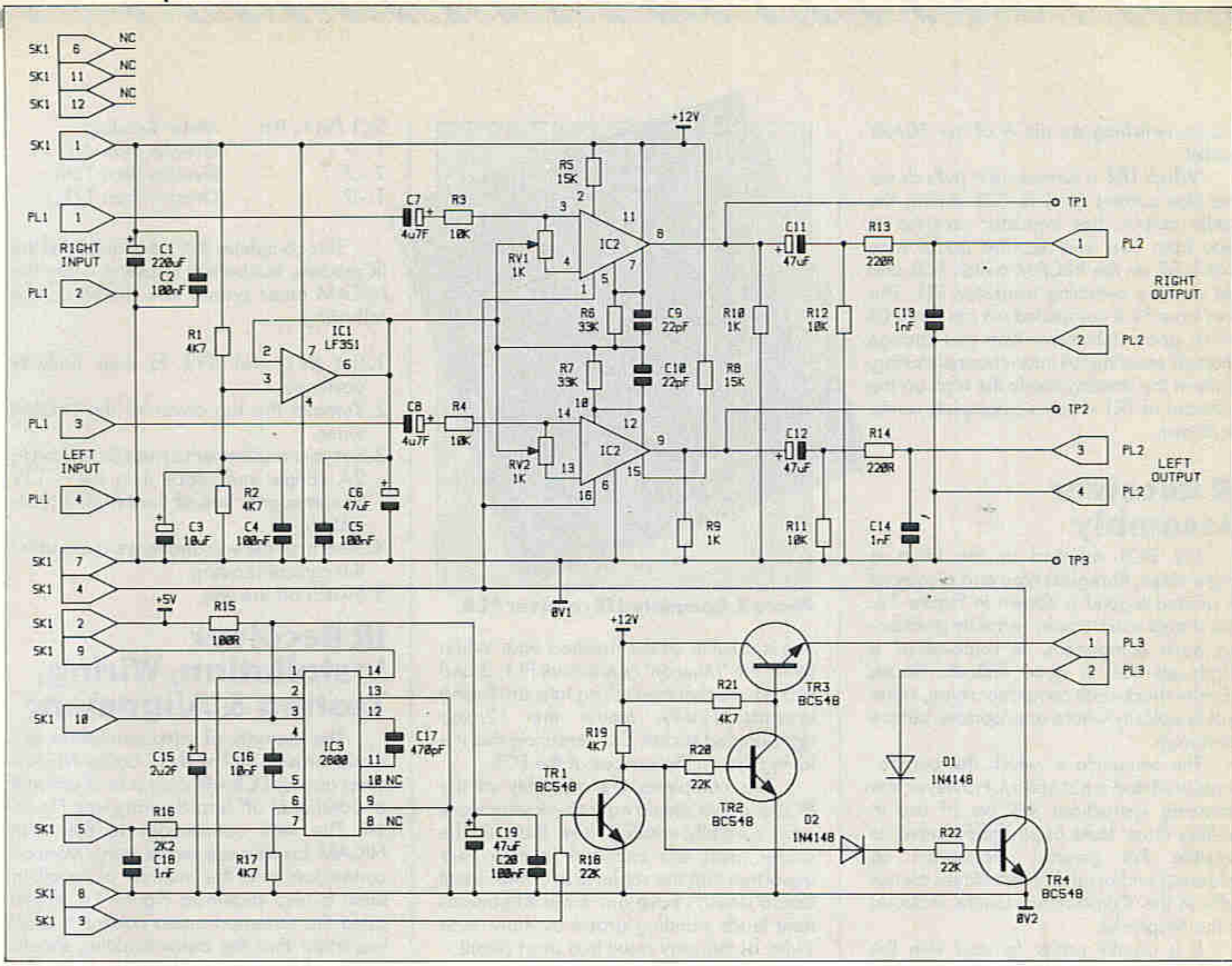


Figure 12. NICAM IR receiver circuit diagram.

automatic gain control (AGC) in this stage and its value has been selected to proved maximum receive sensitivity.

The amplified output signal on pin 12 is connected to the input (pin 11) of the second amplifier (2) via C17. Due to the small value of this capacitor only the higher frequency data pulses will pass through, while the lower frequency interference signals are rejected.

The amplified and filtered signal on pin 5 is then fed via C16 to the input of the pulse separating amplifier (3). This stage is used to extract the maximum amount of intelligible data from the background noise and other unwanted signal elements. The separation threshold is set by a resistor, R17, on pin 6 providing maximum noise immunity while maintaining good receive sensitivity.

The cleaned up data pulses appear on pin 7 and any remaining high frequency noise is suppressed by R16 and C18. This signal is then fed to the M491B on the NICAM display board via pin 5 of SK1. An inverted signal is also available on pin 8 of IC3, but is not required in this particular circuit application.

The DC controlled stereo amplifier and switching circuits are powered from a +12V supply connected to pin 1 of, SK1, which is decoupled by C1 and C2. For the DC controlled stereo amplifier, IC2, to function correctly a half supply reference must be generated, this is provided by an op-amp IC1. The voltage reference applied to its input is derived from the two resistors R1 and R2 which form a potential divider. The op-amp is merely used as a zero gain buffer to provide a low impedance half supply, its output being decoupled by C5 and C6.

2. IC2 is a LM13700 which consists of two current controlled transconductance amplifiers. The amps share a common +12V supply on pin 11, but otherwise operate completely independently of each other. The gain of each amplifier is controlled by the DC bias current feeding pins 1 and 16 of the chip. This control is generated by the M491B on the NICAM display board which is connected via pin 4 of SK1. When powered up an initial volume setting of −14dB is generated which can then be modified by using the −/+ keys on the IR hand controller. As this current increases the sound level will get louder until maximum volume is achieved. The values of resistors R3 to R9 have been calculated to restrict the maximum gain of the amplifiers to 0dB. The minimum volume setting is implemented when any of the following conditions occur:

1. Volume minus (−) key on IR hand controller held in until minimum setting is reached.
2. Sound MUTE key on IR hand controller is operated.
3. Tuner STANDBY key on IR hand controller is operated.
4. TV CHANNEL change (1 to 16, or −/+). Muted for 0·5 of a second.
5. TV station tuning. Muted after three seconds, restored by releasing key.

As the controlling bias current changes, the DC voltage on the output pins 8 and 9 can vary causing a 'click' to be superimposed on the audio signal. To prevent this, the current through the differential inputs on pins 3, 4 and 13, 14 must be balanced out by careful adjustment of the preset resistors RV1 and RV2. The audio path through the IR module is as follows:

Signal designation	Connector reference
Right input signal	Pin 1 of PL1.
Right input screen	Pin 2 of PL1.
Left input signal	Pin 3 of PL1.
Left input screen	Pin 4 of PL1.
Right output signal	Pin 1 of PL2.
Right output screen	Pin 2 of PL2.
Left output signal	Pin 3 of PL2.
Left output screen	Pin 4 of PL2.

3. Transistor switching is used to control SCART function and additional sound muting. In its standby mode the M491B shuts down the 7-segment LED channel display and removes the DC control voltage from pin 3 of SK1. This causes TR1 to turn off which turns on TR2 removing the bias from TR3. When this happens the voltage on its emmitter which is connected to pin 1 of PL3 is switched off. This pin is connected to P32 on the NICAM socket PCB which controls the TV/video

source switching on pin 8 of the SCART socket.

When TR4 is turned on it pulls down the bias current feed to IC2 muting the audio output. This transistor receives its bias from two sources, the audio tune switch S2 on the NICAM switch PCB and the standby switching transistor TR1. The bias from S2 is connected via pin 2 of PL3 which goes high every time you change channel ensuring full inter-channel muting, while in the standby mode the high on the collector of TR1 ensures a complete audio shutdown.

IR Receiver Assembly

The PCB supplied in the kit is a single-sided, fibreglass type and a copy of its printed legend is shown in Figure 13. This should assist you in correctly positioning each component, as removal of a misplaced item is quite difficult. Please double-check each component type, value and its polarity where appropriate, before soldering!

The sequence in which the components are fitted is not critical. However, the following instructions will be of use in making these tasks as straightforward as possible. For general information on soldering and assembly techniques please refer to the 'Constructors' Guide' included in the Maplin kit.

It is usually easier to start with the smaller components. Begin with the resistors R1 to R22 saving the component lead off cuts, using four of these bend them to fit the link positions on the PCB. The test points TP1, 2 and TP3 use small PCB pins to ensure a good connection is made to your meter probes.

Next install the capacitors, diodes, transistors and preset resistors. When fitting the IC sockets, make certain that you fit the appropriate holder in each position, matching its end notch with the block on the legend. Install the IC's ensuring that all the pins go into their sockets and the pin

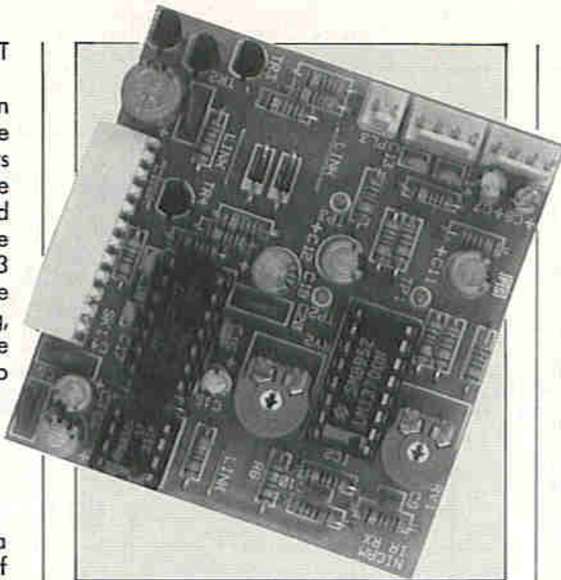


Photo 3. Completed IR receiver PCB.

one marker is at the notched end. When fitting the 'Minicon' connectors PL1, 2 and PL3 ensure that the locking tags are facing inwards. Finally, mount the 12-way right-angled socket, SK1, ensuring that it is laying flat on the surface of the PCB.

This completes the assembly of the PCB and you should now check your work very carefully making sure that all the solder joints are sound. It is also very important that the solder side of the circuit board doesn't have any trimmed component leads standing proud by more than 2mm, as this may result in a short circuit.

Initial IR Receiver Testing

The initial tests ensure that there are no short circuits on the power supply rails. A digital multimeter was used to take the readings from the prototype unit, some of the readings you obtain may vary slightly depending upon the type of meter employed. Set your meter to read kΩ on its 20kΩ resistance range and with its probes either way round the following readings should be obtained:

SK1 Pin to Pin.	Meter Reading.
1 - 7	Greater than 4kΩ
2 - 7	Greater than 16kΩ
1 - 2	Greater than 11kΩ

This completes the initial testing of the IR module, but before installing it into the NICAM tuner system you should do the following:

1. Set RV1 and RV2 to their halfway positions.
2. Remove the top cover of the NICAM tuner.
3. Set your multimeter to read DC mA on its 2A range and place it in the +12V power supply line of the NICAM tuner system.
4. Switch on the unit and make a record of the current reading.
5. Switch off the unit.

IR Receiver Installation, Wiring, Testing & Alignment

The majority of interconnections are made through SK1 and PL1 on the NICAM tuner display PCB with only a small amount of additional off board wiring, see Figure 14. The wire connections to the main NICAM boards are made using Minicon connectors and the method of installing them is also shown in Figure 14. When using the screened audio cable it is most important that the outer braiding should not be able to come into contact with the centre conductor or anything else on the PCB's.

Originally, the wire from P32 on the socket PCB was connected to P31 of the switch PCB and this wire should be long enough to move from P31 to pin 1 of PL3. The new wire from pin 2 is soldered to the top middle tag of the audio tune switch S2, see Photo 4.

The audio lead from the socket PCB is simply moved from PL6 on the NICAM decoder to PL2 on the IR receiver. A short interconnecting lead of approximately

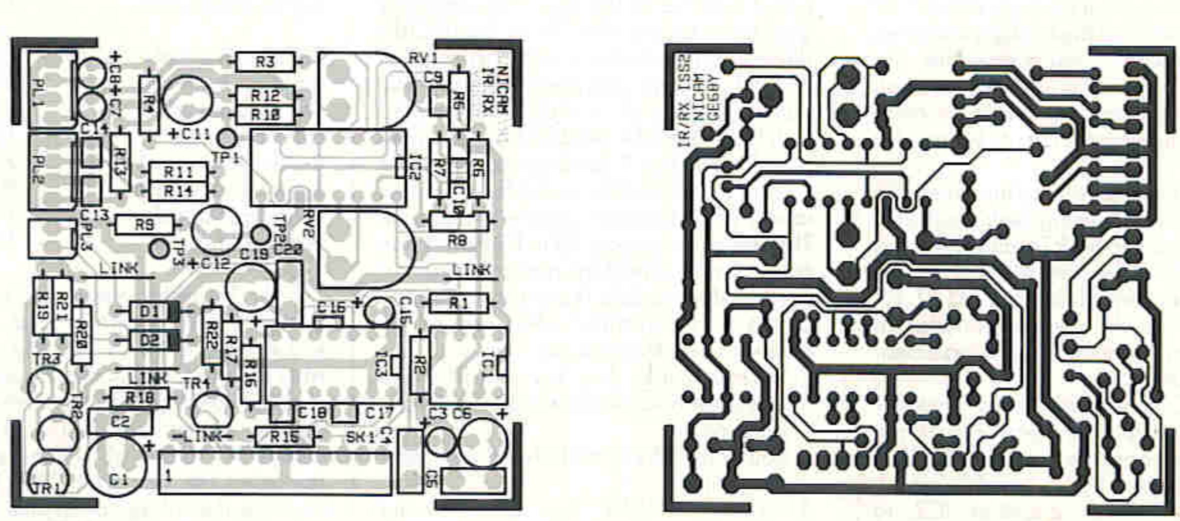


Figure 13. NICAM IR receiver PCB legend.

10mm is used to join the audio output from PL6 to PL1.

To complete the testing and alignment of the unit perform the following:

1. Ensure that SK1 on the IR receiver PCB is pushed fully on to PL1 of the NICAM tuner display board.
2. Remove the Minicon connector from PL1 on the IR receiver module.
3. With your mulitmeter still monitoring the supply current to the NICAM tuner system, switch on the power.
4. Observe the new reading which should have increased by approximately 17mA.
5. Switch off the power, then remove your meter from the DC supply line and set it to read DC volts on its 20V range.
6. Switch the NICAM tuner back on.
7. Using the IR hand controller held at least 200mm away from and pointing at the IR receiver window, hold down the plus (+) volume key for approximately ten seconds.

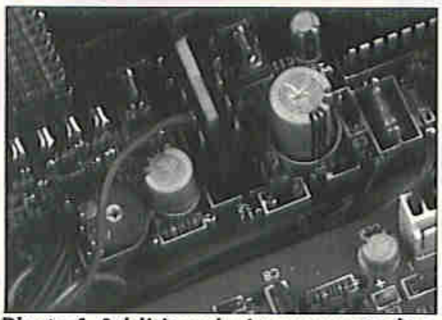


Photo 4. Additional wire connected to Audio Tone Switch.

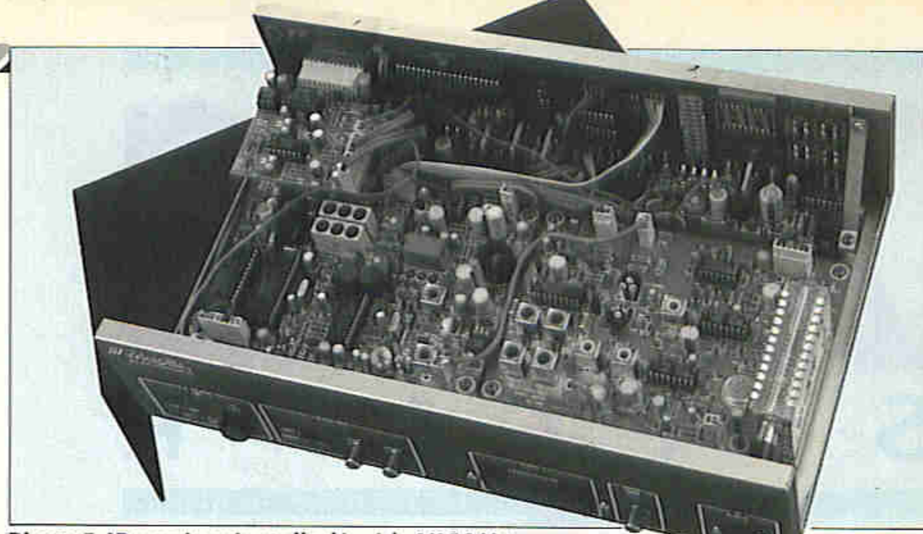


Photo 5. IR receiver installed inside NICAM tuner.

8. Connect your meters test probes, negative to TP3 and positive to TP1.
9. Observe the voltage reading which should be approximately +4·8V.
10. Operate the mute key on the IR hand controller and take note of the new reading.
11. Press the mute key again and carefully adjust RV1 until the voltage matches the new reading.
12. Repeat steps 10 and 11 until no change in voltage can be detected.
13. Move your positive test probe to TP2 and using RV2 repeat steps 9 to 12.
14. Switch off the NICAM tuner, remove your multimeter and reconnect PL1.

Using the Remote Control System

Connect up your TV aerial, video monitor and audio amplifier to the NICAM tuner, then power up all the equipment. The tuner should start up on TV channel one with its audio output level at approximately −14dB. Using the volume control on your amplifier set up a comfortable listening level.

It is recommended that you use good quality alkaline AA or equivalent batteries in the hand-held IR transmitter. Their life expectancy will depend upon make, age, storage temperature and how often the command keys are pressed. In practice this means you should get several months of use before a noticeable deterioration in transmitter range occurs. When the batteries are exhausted it is strongly recommended that you remove them from the unit as any chemical leakage can result in permanent damage.

The IR remote control system has a minimum and maximum operating range. Assuming that the batteries are in tip top condition you can expect a maximum usable range of approximately 4·5 metres. The minimum or close up limit is caused by overloading IR receiver front end and is typically just over 150mm.

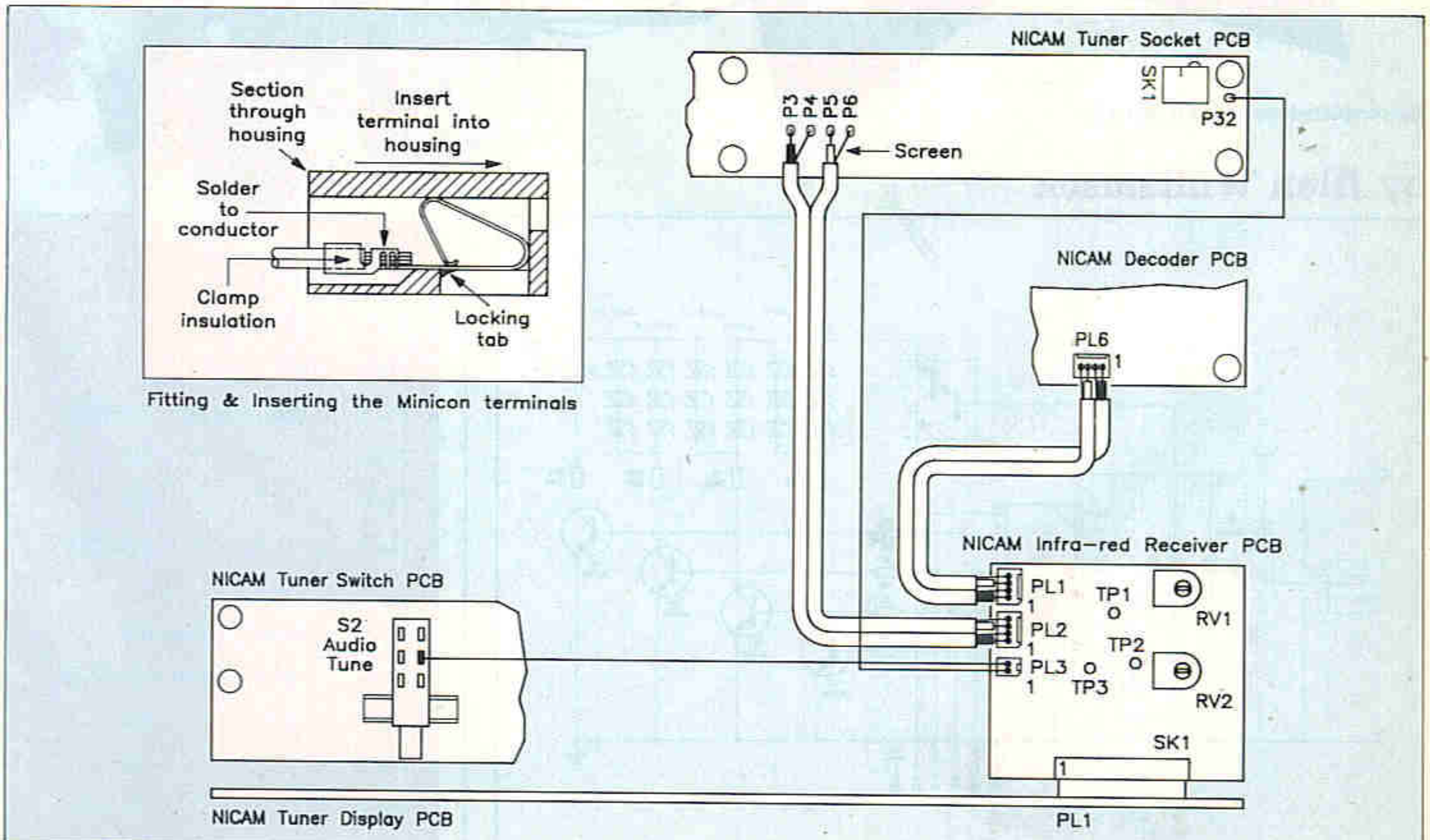


Figure 14. NICAM IR receiver wiring.

Continued on page 54

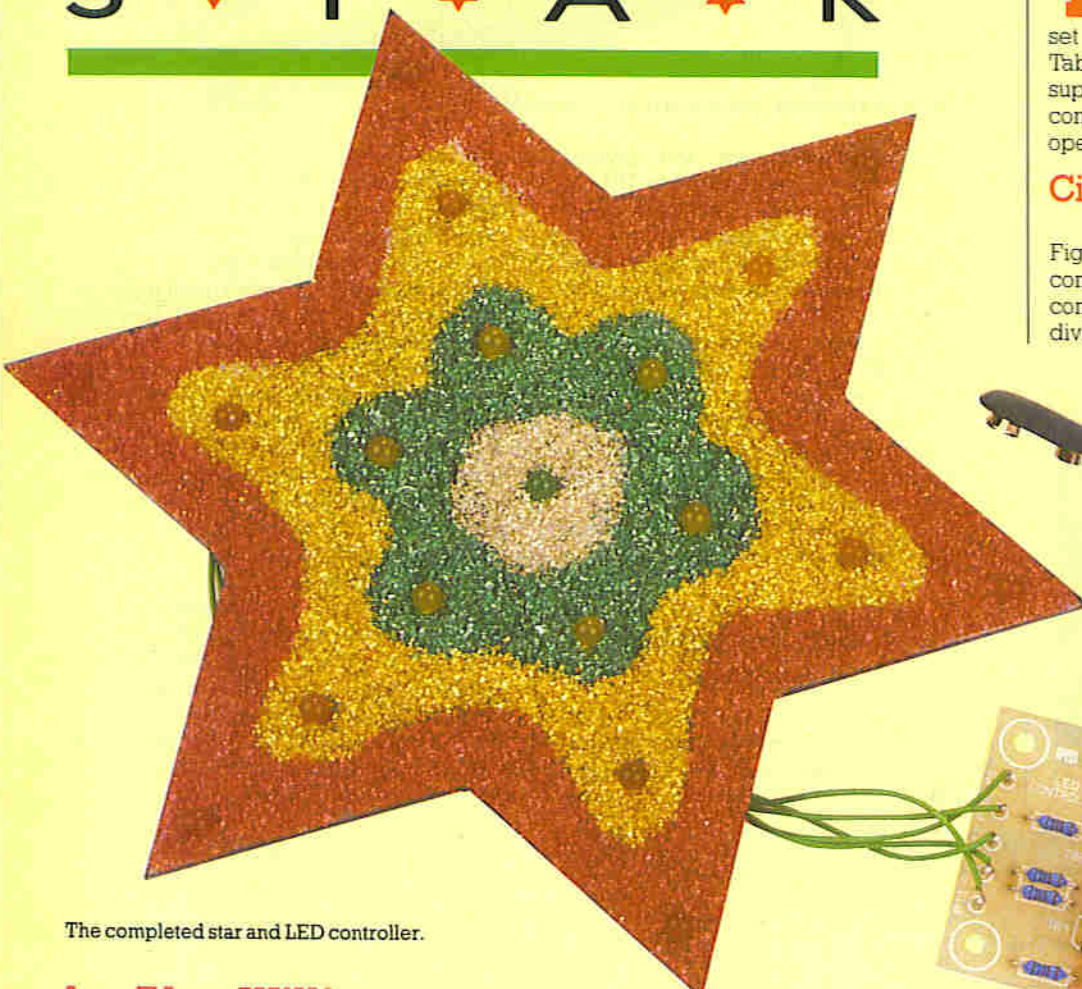
XMAS STAR

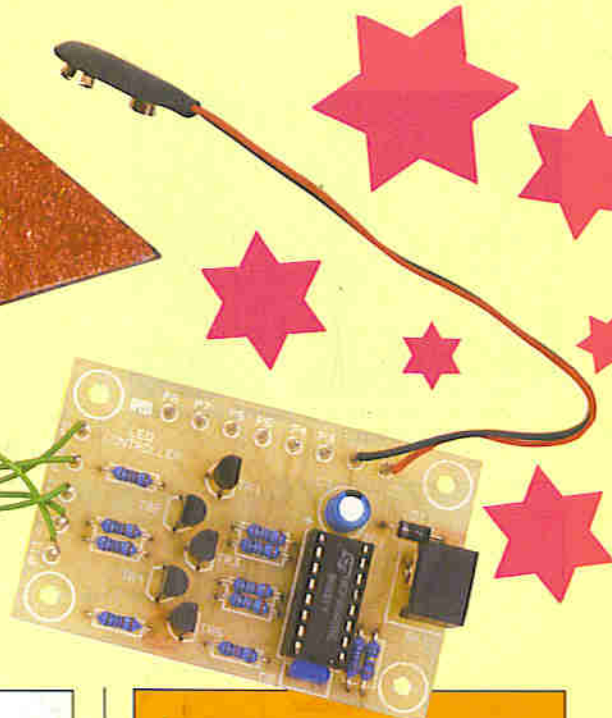
This novelty project is a festive star with lots of flashing LED's to sit upon your Christmas tree. The LED's are switched on and off at different rates by an LED controller.

The controller has two sets of 4-bit binary outputs, one set originating directly from the chip and the other set via open collector transistors. See Table 1. The controller also has a pulsed supply (switching on and off); this helps to conserve power when the controller is operating from a battery.

Circuit Description

Looking at the circuit diagram Figure 1, you will see that the heart of the controller is a CMOS 4060 IC, which contains an oscillator and a 14-stage divider, with an output at most stages of





The completed star and LED controller.

by Alan Williamson

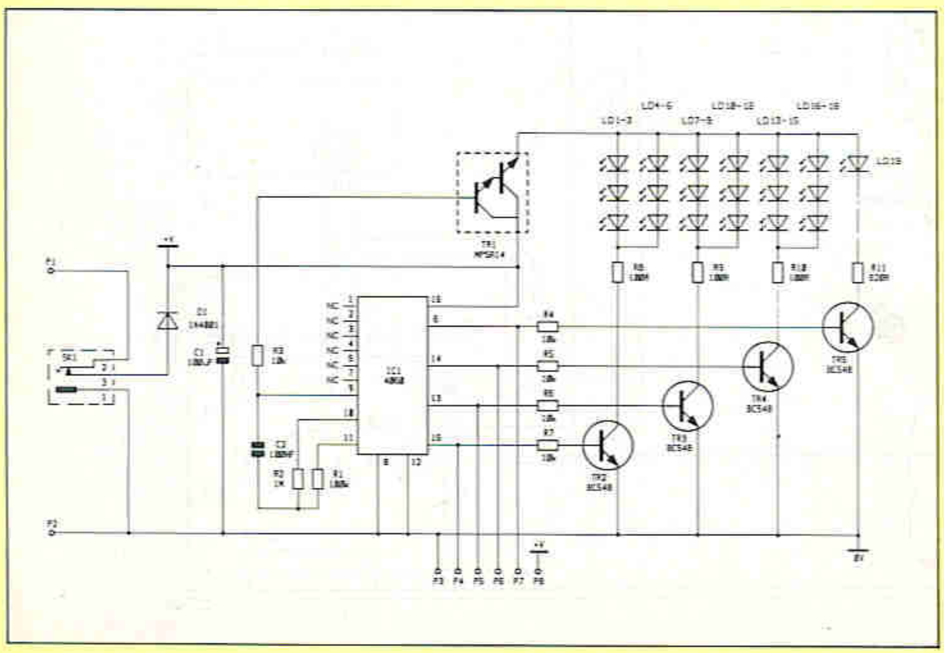


Figure 1. Circuit diagram.

Pin	Description	
Pin 1.	+V Battery	
Pin 2.	0V Battery	
Pin 3.	0V	
Pin 4.	Direct output	D1 (MSB)
Pin 5.	" "	D2
Pin 6.	" "	D3
Pin 7.	" "	D4 (LSB)
Pin 8.	+V	
Pin 9.	Pulsed supply output	
Pin 10.	Open collector	D1 (MSB)
Pin 11.	" "	D2
Pin 12.	" "	D3
Pin 13.	" "	D4 (LSB)

Table 1. Pin description.

division. Stages 7, 8, 9 and 10 (IC pins 6, 14, 13 and 15 respectively) are used to drive transistors TR2 – TR5 via 10kΩ resistors, the LED's being the collector load of each transistor. A direct output of stages 7 through 10 is available at pins 7, 6, 5 and 4. The switching transistor TR1 is connected to the oscillator, using the highest available frequency and therefore avoiding visible flicker in the LED's. The oscillator frequency is determined by the components R2 and C2, and the frequency can be calculated using the formula:

$F\,osc = 1 / 2{\cdot}3 \times R_t \times C_t$

Battery Life

The peak current consumption of the LED controller with all the LED's lit is approximately 70mA, but due to the switching transistor this figure is reduced by half, making the expected life from a PP6 battery around 20 hours. It is therefore recommended that a 6 to 9V DC mains adaptor is used for prolonged use, and a 300mA unregulated supply would be ideal for this application, for example Maplin stock code XX09K.

Construction

Please refer to the Constructors Guide for hints and tips on soldering and constructional techniques.

Referring to the PCB component legend, Figure 2, assemble the PCB as follows.

Begin by finding the MPSA14 transistor and put it to one side so that it will not be placed into the wrong position.

Insert, solder and crop each component starting with the resistors. The veropins are fitted from the track side, remember that C1 and D1 are polarised devices and must be correctly fitted.

Having completed the PCB it should be now cleaned with alcohol, Ultraclene or PCB cleaner (Maplin stock code

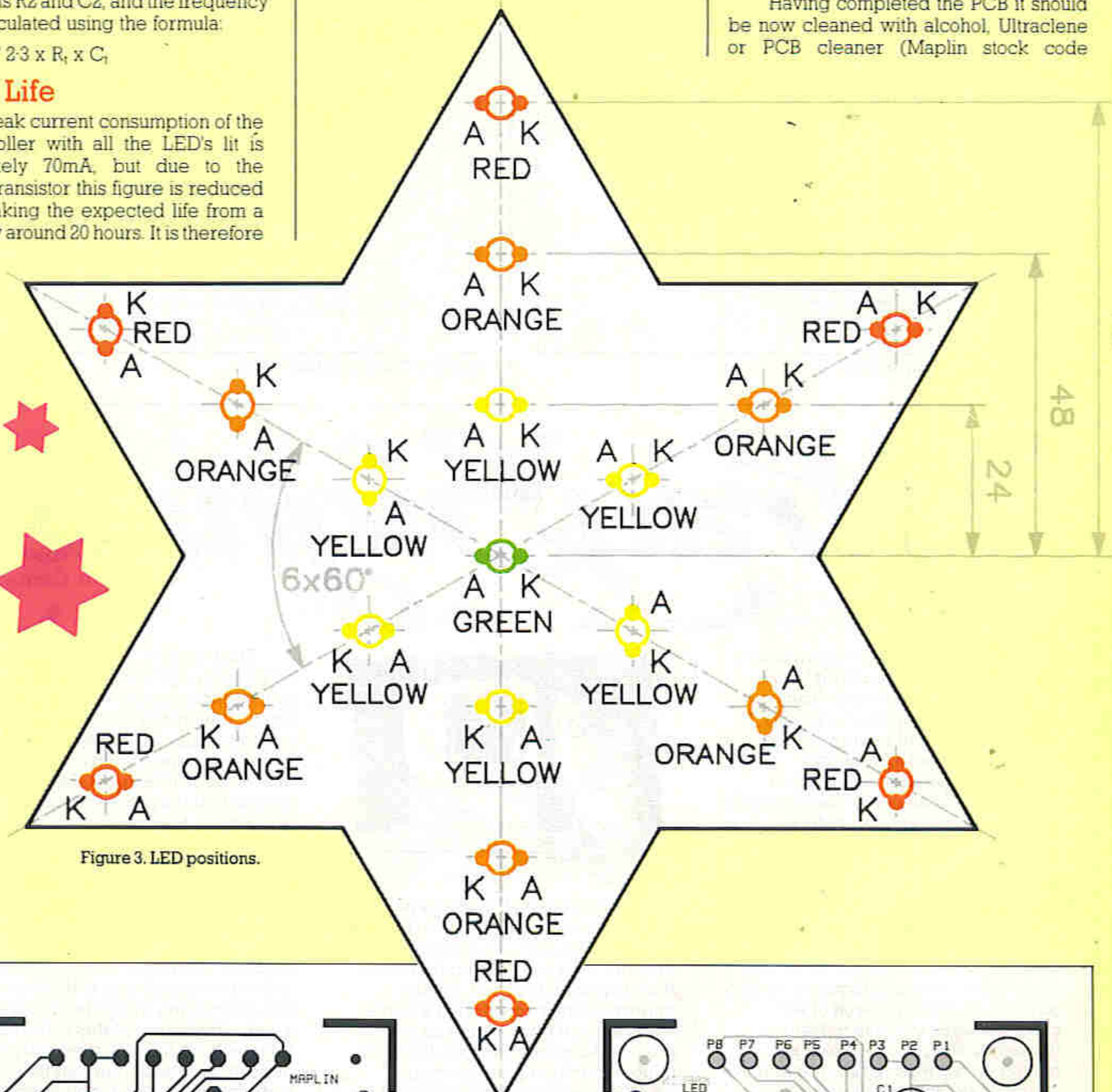


Figure 3. LED positions.

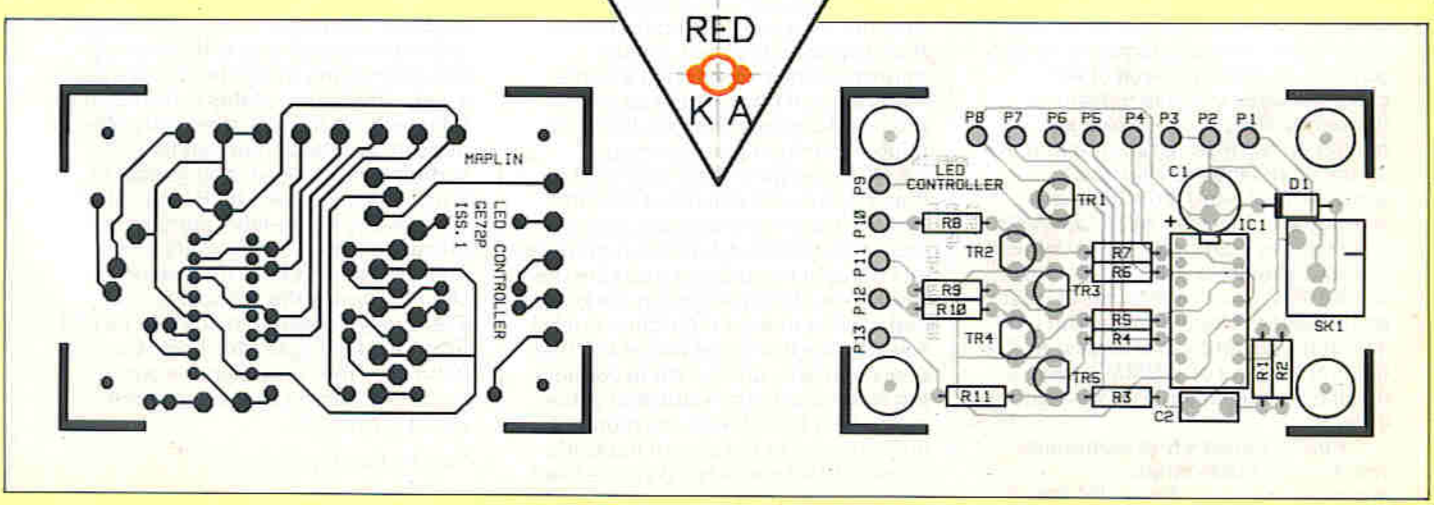


Figure 2. Component legend.

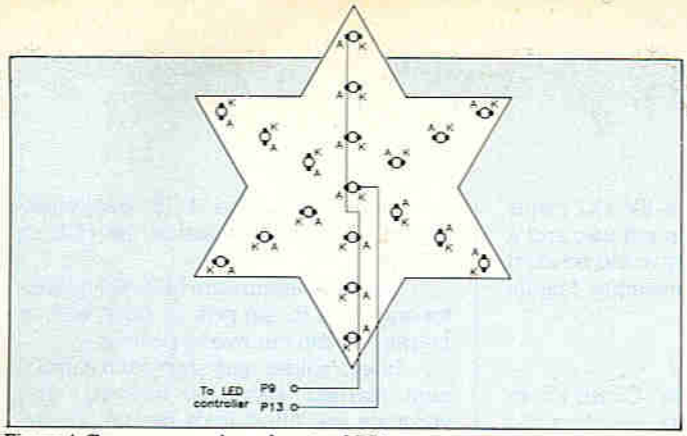


Figure 4. Common supply and centre LED.

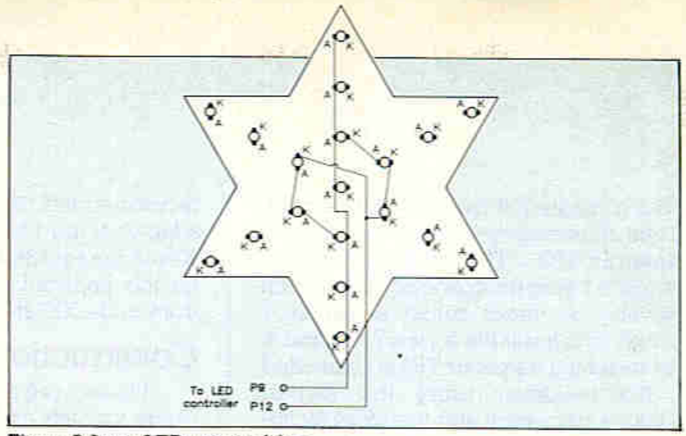


Figure 5. Inner LED group wiring.

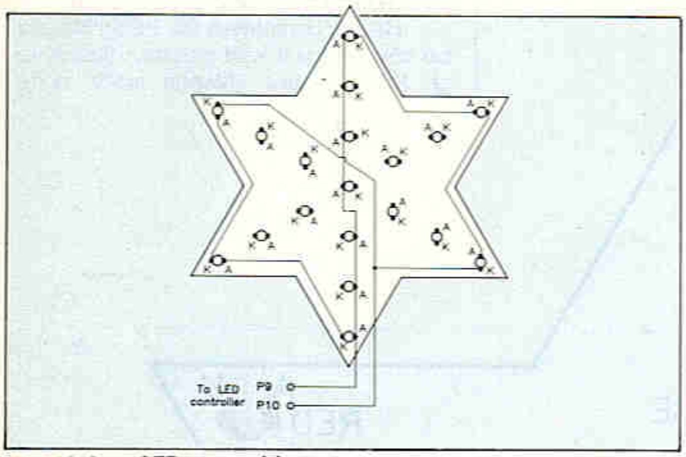


Figure 6. Outer LED group wiring.

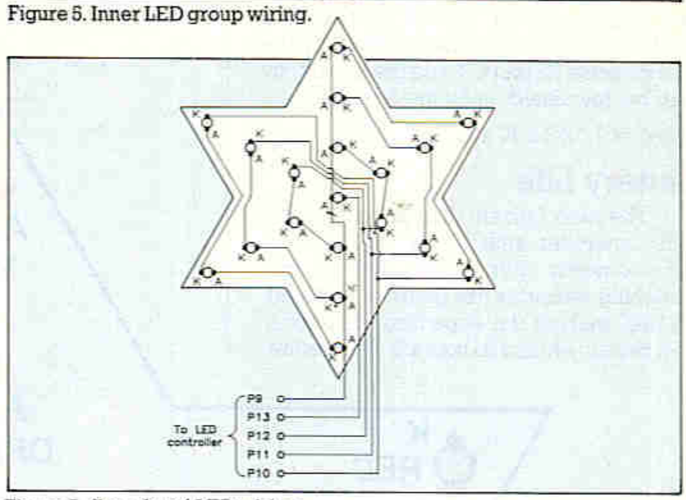


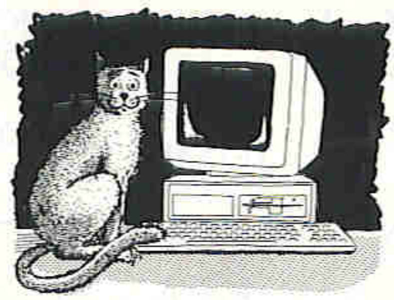
Figure 7. Completed LED wiring.

Stray Signals

by Point Contact

Electronics hobbyists nowadays are lucky in that the essential tools, such as a good multimeter, can be purchased comparatively cheaply. If you are thinking of buying one, my advice would be to go for the traditional type with an analogue meter rather than one of the extremely convenient digital multimeters – unless of course you are lucky enough to be able to run to both: unbiased advice for you from one who is fortunate enough to possess two of each sort. My pocket autoranging DMM travels everywhere with me whilst my Philips PM2521 automatic multimeter, although requiring mains power, has the advantage of AC current ranges and also measures frequency and period. However, neither is so convenient in general use on the workbench as my (now somewhat ancient) little Japanese analogue multimeter. At 30000Ω/volt it admittedly loads a circuit under test slightly more than a DMM with the usual 10MΩ input resistance, at least on the lower voltage ranges. But I like its instant response to changes; trying to follow a trend on a DMM when making an adjustment is not nearly so easy.

Point Contact's first multimeter was a home made affair, incorporating an ex-Govt 3½" 100μA meter which cost 15 shillings at Charles Brittain (Radio) Ltd in Upper St. Martin's Lane – as a schoolkid it took me weeks to save up that much from my pocket money. A later improvement incorporated a home-made current transformer so as to provide AC current ranges. It had no built-in overload protection but nevertheless gave faithful service for many years until one day it died the death through carelessness. It was late and I was tired, but before turning in, I thought I would just measure the resistance of the element in the kettle I had used to make a night-time drink. I selected the low ohms range and then unaccountably proceeded to connect the test prods to the kettle end of the mains lead (which was still plugged in) instead of to the pins of the kettle element! The moral is – if you're tired, don't; just go to bed instead.



Electronics engineers are a bright lot by and large and can hold an intelligent conversation on almost any topic. At work the other day, some of my colleagues fell to discussing whether animals could properly be described as intelligent. Everyone agreed that they could; the only question is, to what degree. On reporting this conversation to Mrs. Point Contact that evening, she stated flatly that our cat understood every word we said, as had our dog Sheba, alas now departed. Whilst I couldn't possibly disagree with her, it must be said that an animal's understanding is definitely limited: like children, they take everything quite literally. We had a vivid illustration of this in the Point Contact household just recently. We noticed that Rusty (our cat) had suddenly taken to spending most of the day in the "spare bedroom", that is to say my home-laboratory-cum-office. He would sit for hours on the floor by the computer or even on the chair in front of the keyboard. Eventually it dawned on us that he had heard me talking to Mrs. Point Contact (who uses the computer as a word processor almost as much as I do) about the mouse.

Yours sincerely,

Point Contact

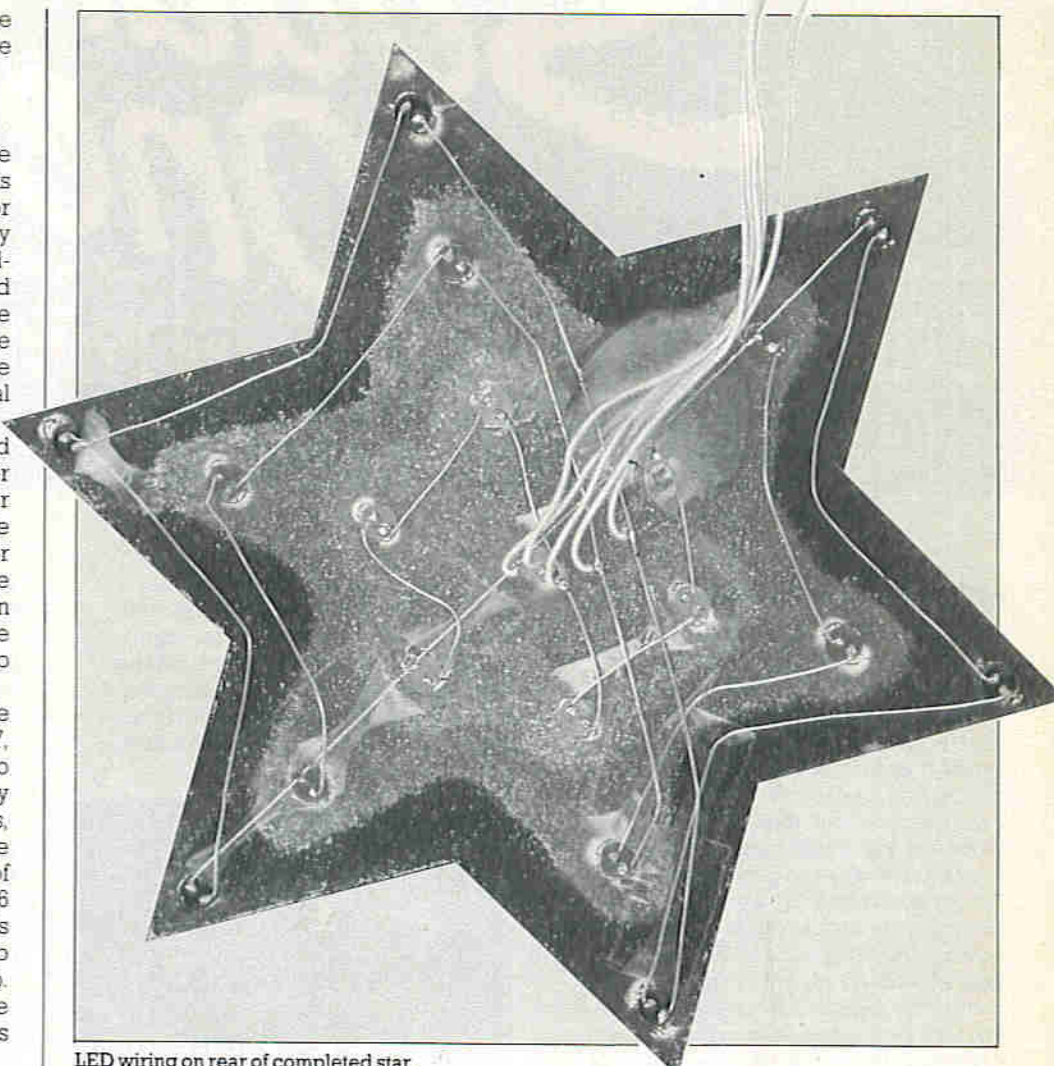
YT66W and YJ45Y), then put it to one side so as not to damage it while you are building the festive star.

Building the Festive Star

Begin by taking a photostat or trace around the star printed on the previous page to use as a template, make a star (or any other shape you may fancy) from any material handy e.g. thin plywood, hardboard, perspex or thick card. Metal and other conductive materials should not be used, otherwise the LED's could become short circuited. Alternatively a decorative star could be purchased from your local Christmas decoration supplier.

Once the star has been cut out and the 5mm holes drilled for the LED's, cover the face of the star with baking foil or aluminium laminate (Maplin stock code XY19V), or alternatively some silver or coloured glitter to make it look pretty. The next job is to glue the LED's into the star in the positions shown in Figure 3. Allow the glue to set before attempting to wire up the LED's.

Connect the LED's using the cable supplied as shown in Figures 4, 5, 6 and 7, the cathode being the shorter of the two leads. Figure 4 shows the common supply to the top anode of each group of LED's, and the lead to the cathode of the centre LED. Figure 5 shows the first group of LED's away from the centre, Figure 6 shows the outer group of LED's which is wired in the same way as the inner group and Figure 7 shows all the LED's wired up. Having now completed the wiring, the LED legs should be trimmed as short as possible.



LED wiring on rear of completed star.

Testing

To test the controller, connect the leads from the star as shown in Figure 1, and connect a PP6 battery to the battery clip or apply 6 to 9 volts DC to the power socket, the pin of the socket being 0V. The LED's will start to flash, if any group of LED's fail to light; check to see if one of the LED's has been inadvertently fitted the wrong way round.

Merry Christmas!

LED CONTROLLER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	1M	1	(M1M)
R2	100k	1	(M100K)
R3-7	10k	5	(M10K)
R8-10	100Ω	3	(M100R)
R11	620Ω	1	(M620R)
CAPICITORS			
C1	100μF 16V Minelect	1	(RA55K)
C2	68nF Monores	1	(RA48C)
SEMICONDUCTORS			
D1	1N4001	1	(QL73Q)
LD1-6	LED Red	6	(WL27E)
LD7-12	LED Orange	6	(WL29G)
LD13-18	LED Yellow	6	(WL30H)
LD19	LED Green	1	(WL28F)
TR1	MPSA14	1	(QH60Q)
TR2-5	BC548	4	(QB73Q)
IC1	4060BE	1	(QW40T)

MISCELLANEOUS			
P1-13	Pin 2145	1 Pkt	(FL24B)
	DIL Socket 16-Pin	1	(BL19V)
	PC Mtg Power Socket	1	(RK37S)
	PP3 Battery Clip	1	(HF28F)
	PC Board	1	(GE72P)
	Constructors' Guide	1	(XH79L)
	Instruction Leaflet	1	(XK37S)
OPTIONAL (not in kit)			
	PP6 Battery	1	(FM03D)

The above items, excluding Optional, are available as a kit:
Order As LP54J (LED Xmas Star Kit) Price £6.95

The following item is also available separately but is not shown in our 1991 catalogue:
LED Controller PCB **Order As GE72P Price £2.75**

Square One

A First Course in the Theory and Practice of Electronics

Part 5 by Graham Dixey C.Eng., M.I.E.E.

Analogue Versus Digital

Electronics is largely concerned with the generation and processing of signals. To quote one example, a signal may be generated by a radio transmitter, sent through the aether, picked up by a receiver and then processed so as to produce an intelligible output, such as sound. In a second, totally different case, when a key on a computer keyboard is struck a signal is also generated. However, this time the signal is processed in such a way as to produce a code, that corresponds to that particular key, which is then stored in the computer's memory. A visible 'echo' appears on the computer screen at the same time, to provide some feedback of what is being typed.

In what ways are the above examples similar, and in what ways different? They are both concerned with communicating; furthermore, the communication may be over a long distance or a short distance. Long distance radio transmissions may be worldwide, or even from space to Earth, or vice-versa; an example of short distance radio communication is a walkie-talkie link within a very limited area, such as inside a building. A computer may communicate over long distances using the public telephone network; it may also communicate over a distance no greater than the physical gap between itself and a printer to which it is connected.

One way in which they are different is in the type of signal that each handles. In the case of the radio system described above, the signal may have an amplitude of many volts at the transmitting end but only be a few millivolts, or even a matter of microvolts, in value at the receiver aerial. The information contained in the radio signal usually takes the form of amplitude, phase or frequency variations of the transmitted wave. This type of signal is described as 'analogue'; such signals are able to take up any one of an infinite number of values between some specified pair of limits. For example, if the potentiometer of Figure 1a was perfect then, as the wiper was moved from the bottom to the top, the output voltage would vary smoothly between zero volts (0V) and the maximum stated value of 10V. Between these two limits it should, in theory, be possible to obtain any voltage we liked.

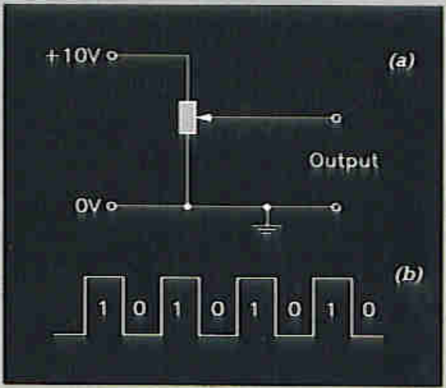


Figure 1. Example of (a) an analogue signal and (b) a digital signal.

The signal handled by the computer circuits will be much more consistent in amplitude (as we shall see in more detail shortly) and the information is contained in what is termed a 'binary pattern'. Such a signal is termed 'digital'. Ignoring tolerance for the time being, a digital signal only ever has two values, which are known as 'logic levels'. One of these is called logic 0 (logic zero), the other is called 'logic 1' (logic one). Figure 1b shows a digital signal, this being termed the 'pulse train'. It is quite obvious from this diagram that the signal fluctuates between the two logic levels and never assumes a value in between. Again assuming a perfect world, the signal would switch between the two states in zero time.

It would be reasonable to ask why a signal, that only ever has two values, should be so useful. It obviously is since so much of modern technology depends upon it. The branch of electronics that is devoted to the study of such signals is termed 'digital electronics', as compared with 'analogue electronics', which concerns itself with the uses of analogue signals.

The need to compute on a grand scale has existed for a long time. Before digital computers became so powerful, reliable and, most importantly, economically viable, much scientific computing was carried out using 'analogue computers', which handled various waveforms as well as D.C. levels (the analogue signals). Values in such computers used the decimal notation (also called denary) that we are familiar with. Because of this familiarity, some of the early work on digital computers attempted to generate and process signals that had ten discrete voltage levels, corresponding to the ten denary values, 0 to 9 inclusive. Such a system was doomed to failure. It is a virtual impossibility to keep such signals anywhere near their nominal values in any practical system and still be able to guarantee telling one from the other without ambiguity.

The answer, of course, is to have as few different voltage levels as possible; the least one can have is two – hence the use of the binary system. It then becomes relatively easy to distinguish between the two levels. It is rather like only having to tell the difference between black and white, without the need to distinguish between eight different grey levels as well! In practice, it is still necessary to assign permissible variations in the values of the two logic levels, since any practical system is bound to introduce voltage drops in the signal path. The penalty for having only two digits is that more digits are needed, to represent a given value, than in decimal. We shall appreciate this better later.

Figure 2 shows possible tolerances for the two logic levels in a system in which logic 0 is nominally represented by 0V and logic 1 by +5V. As will be seen from this figure, any voltage between 0V and +0·8V is accepted as being equivalent to logic 0, while any voltage between +2V and +5V is considered as being a logic 1 level. The region between the two tolerance bands is somewhat

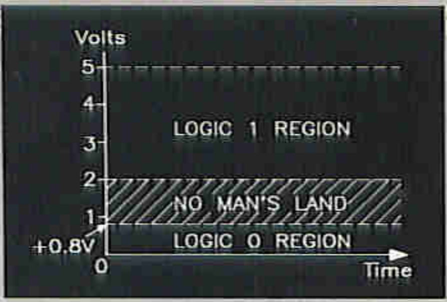


Figure 2. Tolerances on the logic levels in a TTL system.

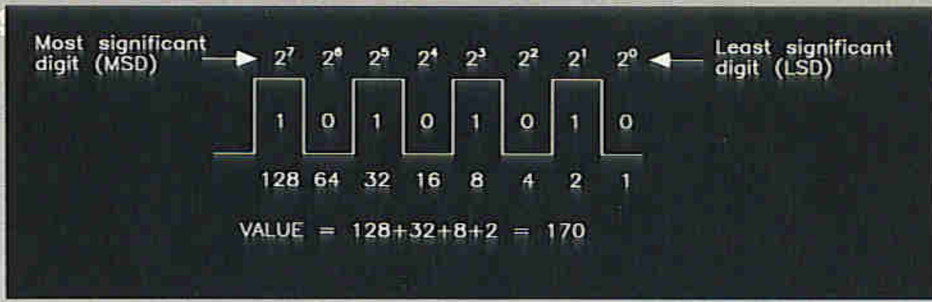


Figure 3. The signal of Figure 1 (b) with column weightings added.

colourfully termed 'no man's land'.

The above discussion seems to show a clear cut division between digital and analogue electronics. Practice shows that, not only are there areas of overlap, but also areas where digital electronics can usurp the former functions of analogue components. Radio, television, audio systems and control systems have traditionally been the preserve of analogue electronics. However, it is possible for an analogue radio signal to carry digital information, such as in the digitised teletext pictures or digital stereo sound. Control systems are invariably controlled by a digital computer, even if an eventual conversion to an analogue signal is made in order to drive analogue machinery.

The Binary Signal

A binary signal is shown in Figure 1b and is seen to consist of a train of pulses. In the example shown, if a pulse represents a logic 1 and the absence of a pulse, a logic 0 then, reading from left to right, the number 10101010 could be said to be represented by this particular binary pattern. This is shown again in Figure 3 with the addition of these 'column values'. The column on the far left is termed the most significant digit (MSD) and the column on the far right the least significant digit (LSD). The principle for interpreting the value is the same as we are used to using in the more familiar decimal system. In the latter system, the number 328 means:

$300 + 20 + 8,$
$= (3 \times 100) + (2 \times 10) + (8 \times 1),$
$= (3 \times 10^2) + 2 \times 10^1) + (8 \times 10^0).$

What the last line shows is that each column has a 'weighting', which is the base (in the decimal system the base is 10) raised to a power which ascends from the column on the far right as we move to the left. For the hundreds column this power is 2, for the tens column it is 1 and for the units column it is 0. (This last fact may be difficult to swallow if maths is not your strong subject!).

The same rule applies to the binary system. Taking the number that we obtained above, namely 10101010, this has eight columns, so that the powers of 2, reading from right to left, will be 0 – 7 inclusive.

This gives:
$(1 \times 2^7) + (0 \times 2^6) + (1 \times 2^5) + (0 \times 2^4) +$
$(1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (0 \times 2^0),$
$= 2^7 + 2^5 + 2^3 + 2^1,$
$= 128 + 32 + 8 + 2,$
$= 170.$

Providing that one can remember or otherwise obtain powers of 2, it is very easy to evaluate binary numbers, as the above example shows. Anything multiplied by 1 equals itself, while anything multiplied by 0 of course equals zero.

Logic Gates – Combinational Logic

As might be expected, combinational logic deals with logic units combined to perform some specific function. The logic unit used is a basic 'building brick' known as a gate. There are only a few different types of gate and it is a characteristic of digital circuits that they may contain many such gates interconnected in what one might sometimes call a 'logic array'. In practice a more specific term will normally be used such as decoder, multiplexer, adder, etc. Whatever the function of a particular block of logic, it will have several inputs and at least one output. The inputs will be designated in some specific way, usually by letters from the beginning of the alphabet: A, B, C, D, etc. The outputs may be designated by letters from later in the alphabet: P, Q, R, or X, Y, Z, for example. Alternatively, they may be designated by the letter F with a numeral attached if there are several outputs: F1, F2, F3, and so on. Other schemes are in use also.

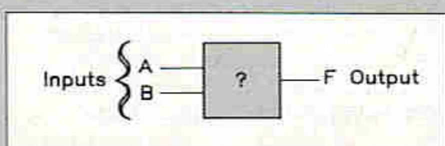


Figure 4. An unspecified logic block with two inputs, A and B, and a single output, F.

$F = A.\overline{B} + \overline{A}.B$

A	B	F
0	0	0
0	1	1
1	0	1
1	1	0

Figure 5. The logic block of Figure 4 now fully described.

Whatever the purpose of any logic block, the way it acts is to give a certain output or outputs in response to particular inputs. Since the signals, whether at inputs or outputs, can only ever be at logic 0 or logic 1, one way of describing the block's function would be to state which combinations of inputs (that is, the binary patterns at the inputs) would cause the outputs to be at logic 1 level. As we shall see shortly, there are several different ways in which this can be done.

Figure 4 shows the way in which a block of logic may be represented. In this case, there are two inputs A and B, and one output, F. This diagram tells us, by itself, nothing more than these bare facts. There is no indication of its function. This information has to be added in some other way. Here are some of the possible methods.

(i) By writing in the name of the function within the outline of the block.
(ii) By means of a truth table.
(iii) By a Boolean algebraic expression.

Sometimes method (i) is adequate, but relies on our knowing exactly what such a named block does.

Method (ii) states specifically what logic levels the output takes up in response to the possible input level combinations.

Method (iii) is the most powerful. From it we can derive method (ii) anyway, assuming we want to. Also it allows us to design the contents of the block, or to know what the block is likely to contain, if it already exists.

In Figure 5 the logic block of Figure 4 has been taken and all three methods applied to it.

(i) The name given, that describes its function, is 'exclusive-OR' gate.
(ii) A truth table for this block shows that, only when the two inputs A and B, have different logic levels is the output F equal to logic 1.
(iii) The Boolean expression that describes the block is

$F = A.\overline{B} + \overline{A}.B$

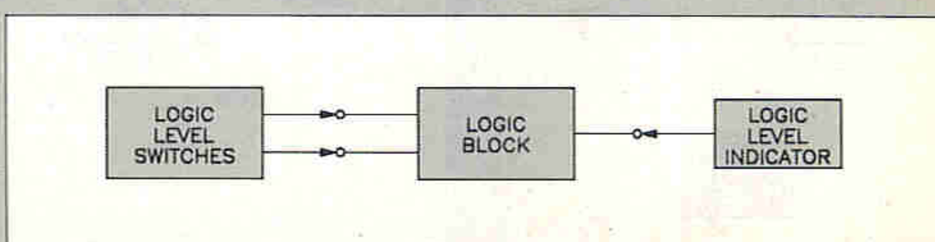
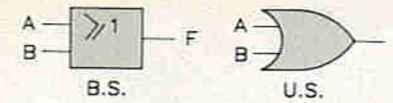


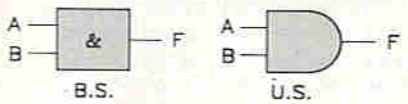
Figure 6. Obtaining a truth table experimentally.



F = A+B

A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

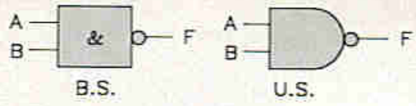
Figure 7. The 2-input OR gate.



F = A.B

A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

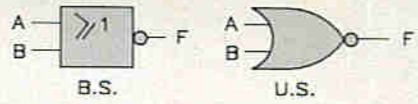
Figure 8. The 2-input AND gate.



F = $\overline{A.B}$

A	B	F
0	0	1
0	1	1
1	0	1
1	1	0

NAND



F = $\overline{A+B}$

A	B	F
0	0	1
0	1	0
1	0	0
1	1	0

NOR

Figure 10. The NAND and NOR gates.

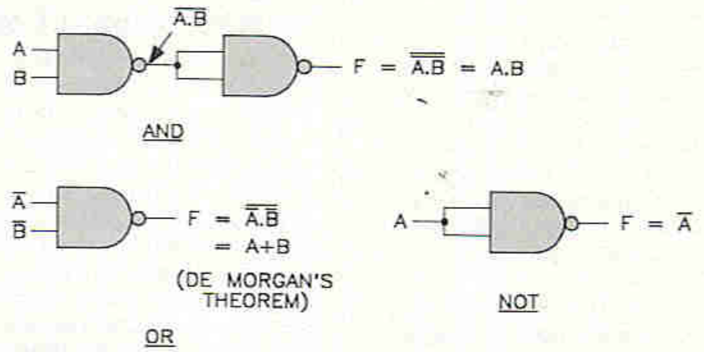


Figure 11. The NAND gate used to provide AND/OR/NOT logic.

Truth Tables

A look at the truth table for the exclusive-OR gate of Figure 5 shows that it has a column for each of the inputs (just two, A and B, in this case), and a column for each of the outputs (just one, F, in this case). Each row contains a unique combination of the inputs and the logic level that will be obtained at the output in response to that combination.

Since there are only two inputs, each of which can only take up one of two possible levels, there will be $2^2 = 4$ combinations. As seen, these are: 00, 01, 10 and 11. The outputs obtained, respectively, for each of the combinations are: 0, 1, 1 and 0. In general, if there are 'N' inputs the number of combinations will always be 2^N.

Thus, three inputs A, B and C will have $2^3 = 8$ combinations; four inputs A, B, C and D will have $2^4 = 16$ combinations, and so on.

The interpretation of a truth table is that it tells us which input combinations produce logic 1 at the output, and which combinations produce logic 0 outputs. Truth tables may be given as the statement of a problem, usually where a circuit with a particular function is to be designed, or they may be obtained experimentally, as shown in Figure 6, on an existing logic circuit. All that is needed are switches that provide the required input logic levels and some form of visual indicator: LED driver circuit, logic probe, etc, to determine the output level in each case.

There are many practical uses for circuits of this type. It might be required to switch a relay, for example, when a certain input combination occurs; or a certain block of memory in a computer should be selected (the basis of memory decoding); or the output could be the result of a mathematical operation, as in adders and other arithmetic circuits.

Boolean Algebra

It is less easy to discuss this topic in just a few paragraphs. It is not my intention to get into Boolean algebra in any depth, but just to explain a few basic ideas, enough to allow a sensible investigation of logic circuits to be made. It is a form of algebra in that variables are represented by letters of the alphabet; logical operations can be performed on these variables so as to describe the performance of a logic circuit. To the newcomer the operators used can be initially confusing because they mean different things in the more familiar context of 'normal' maths. For example:

The statement F = A + B means A OR B and not A PLUS B.

The statement F = A.B means A AND B and not A TIMES B.

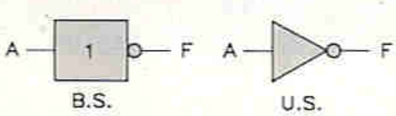
There is another operator which consists of a 'bar' over the variable, e.g. $\overline{A}$ (usually called NOT A or sometimes A-bar). It means the 'inverse of A' or the 'opposite of A'. Thus, if A = 0 then $\overline{A}$ = 1 and vice-versa. Some Boolean algebraic statements look very complex indeed but, when they are examined carefully, are found to consist solely of combinations of AND, OR and NOT functions. These will now be explained.

The OR Function

This implies some alternative possibilities. In fact it means that the output of the logic gate (known as an OR gate) will be logic 1 if:

EITHER A = 1; OR B = 1; OR A = B = 1

Figure 7 shows the British Standard (BS) and U.S. symbols for a 2-input OR gate, together with its truth table.



F = $\overline{A}$

A	F
0	1
1	0

Figure 9. The inverter (NOT gate).

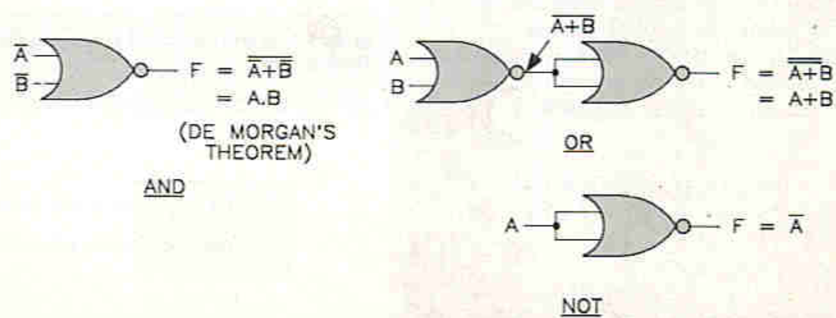


Figure 12. The NOR gate used to provide AND/OR/NOT logic.

The AND Function

This implies some coincidence. It means that the output of the logic gate (known as an AND gate) will be logic 1 if:

A and B = 1 only; otherwise the output = logic 0.

Figure 8 shows the BS and U.S. symbols for a 2-input AND gate, together with its truth table.

The NOT Function (inverter)

There is a type of gate (shown in Figure 9) which has just one input and one output. The 'bubble' at its output tells us that it will invert the input logic level. The truth table shows this clearly. If the input A = 1; then F = 0 and vice-versa.

NAND and NOR Logic

Gates are available as multiple assemblies within a single IC package. For example, one 14-pin IC can hold either four 2-input AND gates; four 2-input OR gates or six inverts. If a certain circuit is designed that contain, say, three AND gates, two OR gates and an inverter, it would be necessary to use three IC's if AND/OR/NOT logic is used. This is wasteful and takes up an unreasonable amount of board space. It would be much better if only one type of gate could be used, since this would normally lead to the use of a smaller number of IC's.

As it happens, the three functions discussed above, namely AND, OR and NOT, can be realised using other types of gate, known as NAND and NOR gates. The term NAND is derived from a combination of the terms NOT and AND, while NOR comes from NOT and OR combined. The symbols for these gates, with their truth tables are shown in Figure 10. Compare the NAND truth table with that for the AND gate in Figure 8, and do the same for the NOR gate, comparing it with Figure 7. They are seen to be opposites, as expected. In terms of Boolean algebra, the output has a bar over it to indicate the NOT part of the NAND or NOR function.

Figure 11 shows how to connect NAND gates to obtain the AND, OR and NOT functions, while Figure 12 shows the same for NOR gates. In both cases, an inverter can be obtained by strapping together all input pins. The AND function is nothing more than an inversion following the NAND function. Similarly, for the NOR gate the OR function is just an inversion following the NOR function. Getting OR from NAND and AND from NOR is easy but not very obvious. No proof is offered here but an explanation under the heading 'de Morgan's theorem' will be found at the end of this article.

Breadboarding Logic Circuits

The easiest way of building logic circuits quickly is by plugging the IC's into pin-boards and making solid copper wire interconnections. A 5V power supply will be needed for testing TTL chips. (TTL is a particularly common logic family, whose type numbers begin with the digits 74). It is best to wire up a line of holes as the '+5V bus' and a second line of holes as the '0V bus'. The power pins on the IC's can then be connected to these buses with short connecting leads. On many TTL IC's, pin 7 is the 0V connection and pin 14 is +5V, but it pays to check first if not sure, since there are exceptions to this rule. To make TTL circuits perform reliably, decoupling capacitors should be included. These should be 10-100nF short-lead disc ceramics and must be connected directly across the power pins on the chip. The rule is a minimum of one decoupling capacitor for four gate packages. More can be used, e.g. one per IC, plus a single $10\mu F$ 6V tantalum electrolytic across the power where it enters the board.

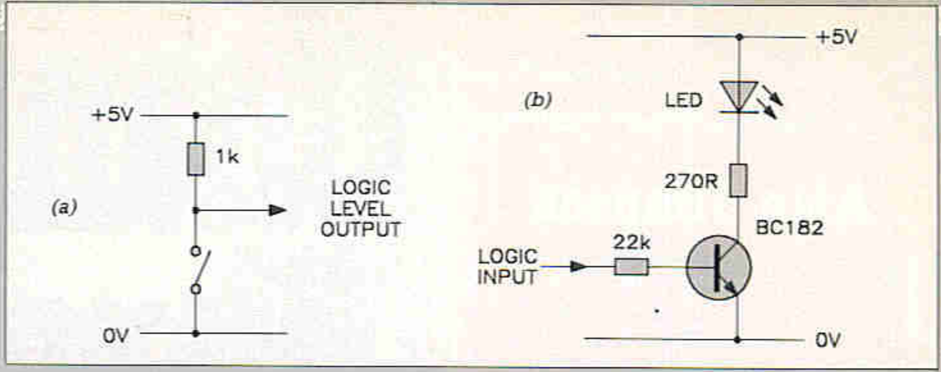


Figure 13. Circuits for (a) a logic input switch and (b) an LED logic level indicator.

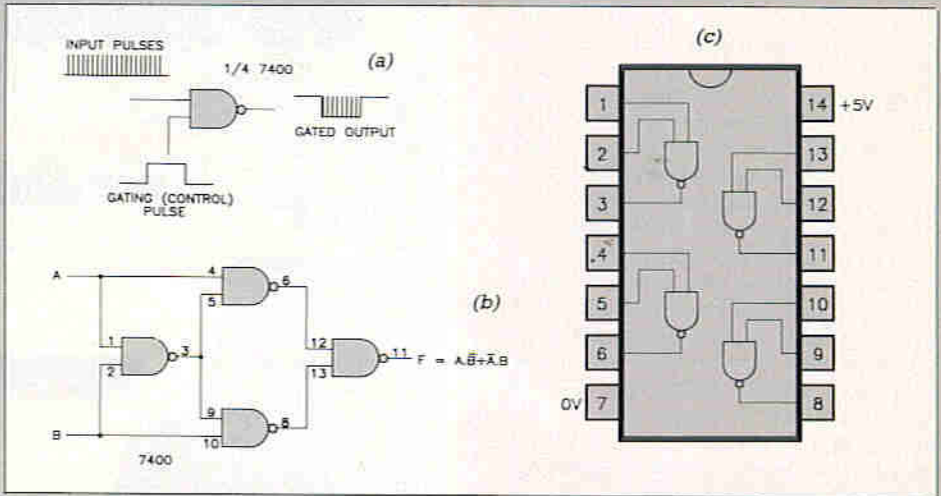


Figure 14. Circuits for (a) gating a train of pulses, (b) the exclusive-OR gate, and (c) the pin-out of the 7400.

Figure 13 shows the circuits for (a) a logic input switch and (b) an LED level indicator. It may be convenient to make up a test box with, say, four of each of these, provided with 4mm sockets to allow connection to the board.

Finally, Figure 14 shows two circuits that can be wired up and tested. The first of these (a) justifies the use of the term 'gate' since it shows how a logic level can be applied to control or 'gate' the flow of pulses from input to output. This control input, when at logic 1, allows pulses to pass through freely, but when at logic 0, the output of the gate is 'stuck' at logic 1. It can be tested by using the TTL oscillator/flasher described in the first part of this series (*Electronics* No.37). Pulses can be tapped off from either pin 3 of the 555 IC or from the collector of the LED driver transistor. The output of the gate can be monitored with either an LED indicator or a logic probe.

Figure 14b is the circuit for an exclusive-OR gate. It is suggested that this is wired up and its truth table taken by using a pair of input switches to provide the input combinations and one of the types of indicator mentioned above to obtain the corresponding outputs. The truth table obtained should then be compared with that given in Figure 5 to verify the results.

Both circuits require just one TTL package, in this case the first in the series, a 7400 quad 2-input NAND gate. The pin-out for this is also given in Figure 14c.

De Morgan's Theorem

This useful theorem has two forms as given below.

(i) $\overline{A + B} = \overline{A}.\overline{B}$, which may be written as $A + B = \overline{\overline{A}.\overline{B}}$ instead, merely by transferring the bar across from left to right.

If the inputs to a 2-input NAND gate are $\overline{A}$ and $\overline{B}$, the output from the gate will be $\overline{\overline{A}.\overline{B}}$. The above theorem shows that this equals A + B.

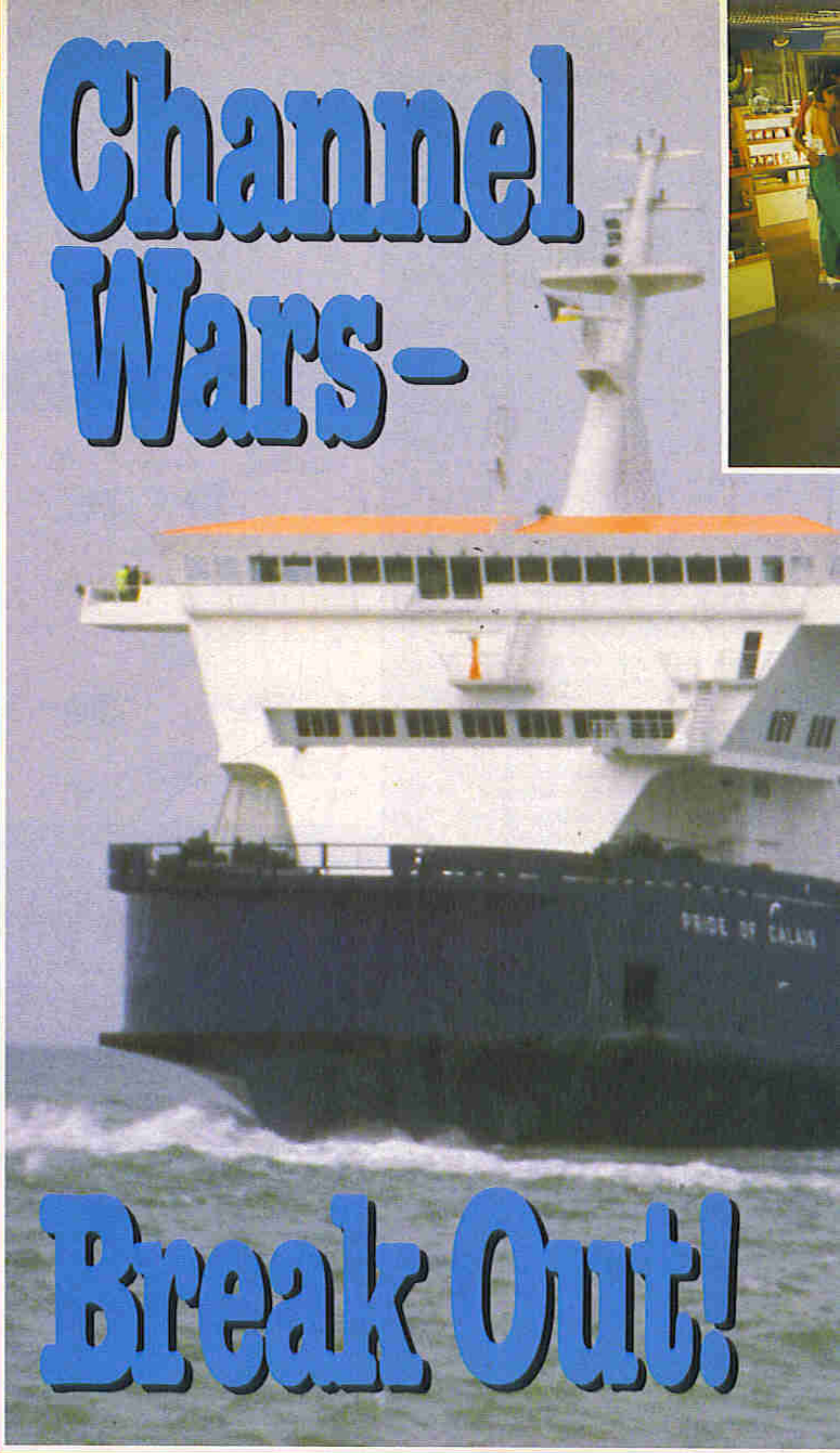
Thus, a NAND gate behaves as an OR gate if the inputs are first inverted.

(ii) $\overline{A.B} = \overline{A} + \overline{B}$ or, alternatively, $A.B = \overline{\overline{A} + \overline{B}}$, similar to above.

If the inputs to a 2-input NOR gate are $\overline{A}$ and $\overline{B}$, the output from the gate will be $\overline{\overline{A} + \overline{B}}$. The above theorem shows that this equals A.B.

Thus, a NOR gate will behave as an AND gate if the inputs are first inverted.

Channel Wars - Break Out!



by Alan Simpson

There is no need to run for cover, but cross channel ferry wars have broken out. The two main contenders, P&O European Ferries and the Scandinavian-owned Sealink companies, are not only in combat mode with each other, but both are having to face up to a common enemy, Eurotunnel. Although the channel tunnel will not be operational for several years yet, the ferry operators are not wasting any time in extending and refitting their fleet. There is talk that they may combine forces to offer a shuttle-like cross channel service.

But this is one marketing war that is producing a clear victor – the ferry passenger. Taking the ferry is being promoted not just as a cost effective way of getting you or your car plus family across that stretch of water separating Britain from the rest of Europe, but as a major part of the holiday itself. Not so much an away-day, more a welcome break, allowing the driver and passengers the opportunity to relax in comfortable surroundings. Both P&O and Sealink are investing heavily in new super ferries, the aim of which is to convert the typical ferry crossing into a mini cruise.

For the ferry companies, the emphasis is now firmly on quality. P&O have even introduced a Club Class service out of Dover where for a supplement of £5 for each single journey, passengers can relax in exclusive lounges with exclusive stewards on hand. Meanwhile business executives can, at a cost of £7.50 per journey, enjoy complimentary tea, coffee and newspapers plus the availability of such travelling essentials as telephone, fax machines (if the ship is in range). Also provided are writing desks – what no executive workstations and meeting rooms?

Trade is Brisk

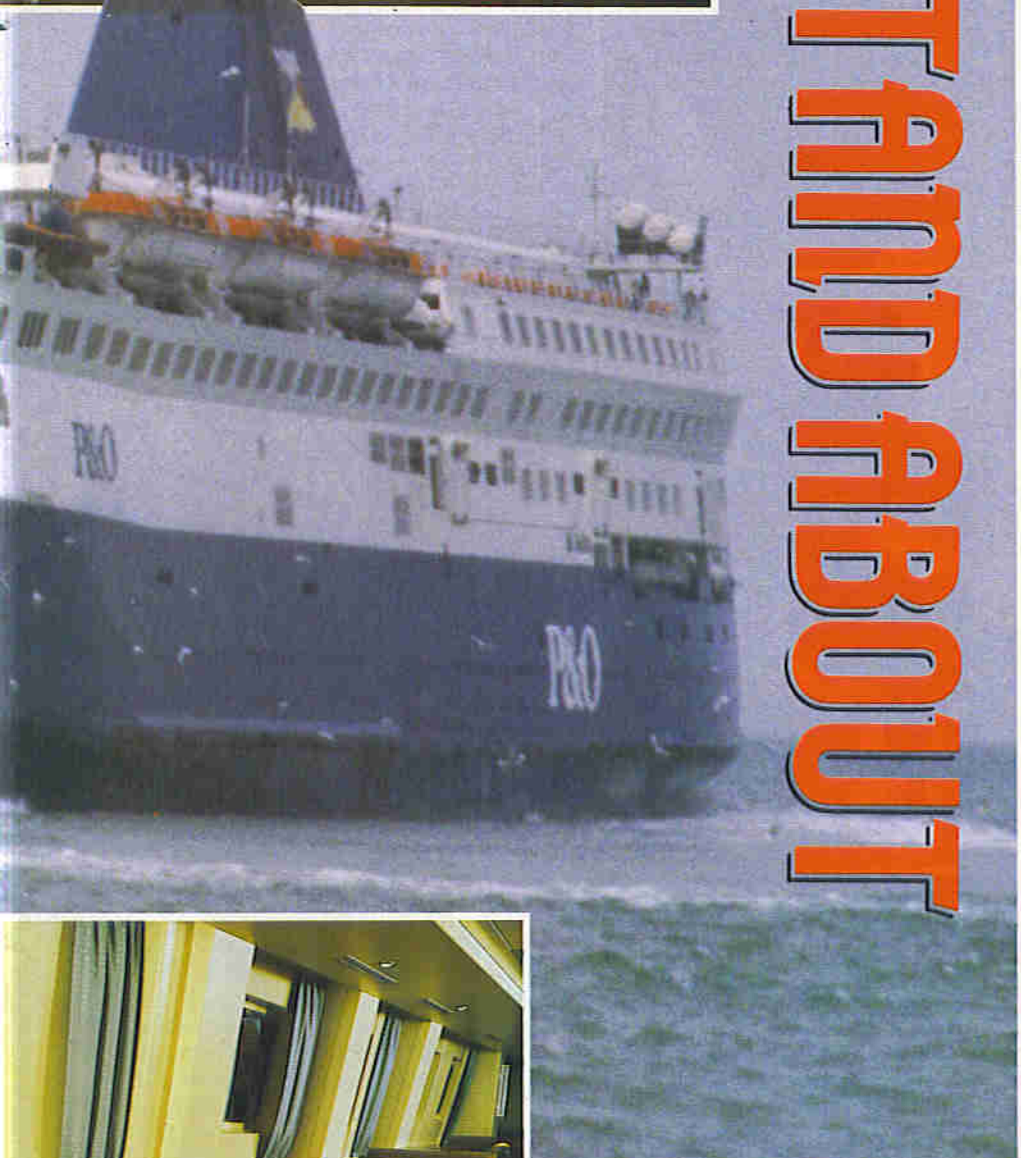
Certainly cross channel trade is brisk. For the first nine months this year, market leader P&O European Ferries carried on services from Dover, Portsmouth and Felixstowe a record 10m passengers and over 1·7m tourist vehicles. With year round growth for the industry exceeding 12%, it is no wonder that the Eurotunnel construction teams are busily digging their way across (or rather under) the channel. But by the time the tunnels meet and become fully operational, the ferry companies will have in place a fleet of super ferries. These will feature such onboard delights as video viewing rooms, discos, specialist restaurants and ample space for relaxing or strolling on the decks. At the same time, P&O is introducing more up-market tax free shops, less St Michael and C&A modes, more Pierre Cardin, Adidas and Umbro ranges.

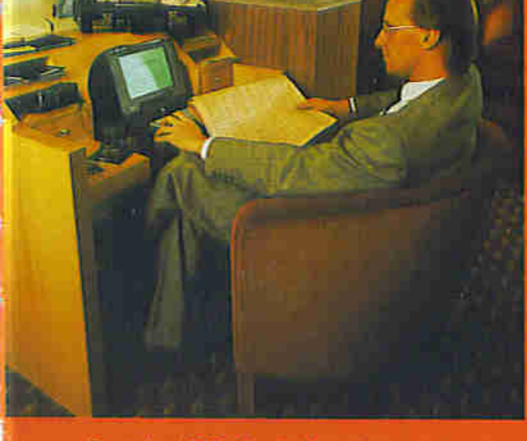
Already P&O operate the largest and fastest fleet of luxurious super-ferries on the Dover to Calais route with the largest ship carrying up to 2,300 passengers and 650 cars and vehicles. At the same time some of their smaller ships are undergoing extensive refurbishment.

But is it not just the ferry operators who are involved in smartening up their facilities. Passengers arriving at Dover Harbour will be issued with a smart card-type ticket. This will automatically direct them to the right ship at the right time. At various points in the dock, the card can be swiped through a terminal to get a sailing update. High tech is even helping the truck driver. His load documentation can be faxed across the channel in advance, reducing as a result, the customs clearance timescale.

High tech is even present on board. The shops on board the P&O ships are equipped with Electronic Point of Sale systems with an automatic swipe facility to speed up payment by credit card. The EPoS and credit card data is automatically downloaded twice a day from the on-board compu-

OUT AND ABOUT





Top: On-board shopping.
Centre: Ferry leaving port.
Bottom: Business facilities.

ter to the operator's shore station by means of data cellular radio links. Apart from providing stock updates and management sales information, the EPoS system acts as a security feature, keeping tabs on what has been – or has not been sold.

Comms on Board

Rather like the P&O sailing schedules, there is no shortage of on-board communication facilities. Passengers can make use of the Cellnet cellular system for which phone cards are on sale at onboard kiosks, or make calls via the radio officer.

As can be expected, the fleet operates an extensive comms network. Shore-based managers can dial individual ships from their office desks using their own private VHF radio link. A P&O development 'Smart Patch' allows calls to be directly routed to specific officers on board. Ship to shore administration messages and data traffic is handled by the Cellnet network service. The range is no problem on the Dover to Calais route, though the signals only extend halfway across the Dover to Zeebrugge route.

Each ship has an on-board telephone system based on an automatic central telephone exchange. In addition there is a set of hand-held Motorola UHF portable phones to help the crew keep in touch should the ships main comms network go down. These phones are also used to assist shore-based loading procedures.

At the centre of the comms activities is the ship's radio officer. He can route voice or data calls via a powerful transmitter to the coast guard radio stations where it can be switched into the public telephone network.

Keeping in Touch

Shore based managers meanwhile can keep in touch with the ship by a mix of letter, telephone or fax. Such matters as special loading requirement and the finalised loading manifesto provide details of the number of passengers, cars and freight are speedily relayed. The manifesto which is also transmitted ahead of the ship to the destination port, is also used by the Navigation officer on the bridge to calculate the load stability of the ship by means of a computer.

As Mike Ridley, Fleet Director of P&O European Ferries (Dover) says, "Like most businesses, a lot of paper and correspondence is generated. Our aim is to streamline the data, image, fax and telex flows in order to reduce that paper flow". The company have made a start by installing a multi-user DEC MicroVax computer on board one of their ships, and just as soon as all any remaining bugs have been sorted out, the twin unit fail-safe system and terminals will be installed on all eleven fleet vessels.

The on-board computer will handle such matters as general correspondence, planned maintenance and stock control/spare part ordering by the engineering team. A compilation of specified annual dry docking and refit routines will be collated as well as personnel records. These will include electronic time sheets and the logging of training programmes and records – an important factor as all staff have to

Above: Relax in the lounge.
Right: Kiddies compare toys whilst mum and dad select duty free's.

P&O Ferry Contest

1. How many land miles is it from Dover to Calais?
a) 15. b) 30. or c) 22.
2. What is the approximate sea crossing time from Dover to Calais?
a) 1 hour. b) 1hour 35mins. or c) 1 hour 15 minutes.
3. Is Zeebrugge in:
a). Holland. b) Belgium. c) France or d) Germany.
4. An international insurance certificate is strongly recommended when taking your car abroad. Is it known as:
a) The Blue Card. b) The Orange Card. or c) The Green Card.

undergo statutory training and fire drills. As each ship has a more or less regular set of four or five crews, there will be no shortage of data.

Training is also in hand for all officers covering wordprocessing and spreadsheet operations. "There is nothing," says Mike, "more useless than having a computer on board a ship, which is not being used to its full potential." Already the on-board PC is being used to handle the transfer of information (by floppy disk) so skills are already present.

Good computer and comms facilities are essential says Mike and the aim is to have eleven floating workstations. "Our main desire is to develop systems and routines which will minimise the time officers and crew members spend on administration, allowing them more time to devote to the well-being of the passenger". In addition the move to on-board information will benefit passengers. Already the company are reviewing the possibility of issuing regularly issued fax weather reports for passengers.

P&O technical teams are now looking at ways of improving their comms and computer link-up, with the SATCOM satellite seen as being a possible way forward, particularly for data transfer. In fact the ferry operators now have a wide choice of radio services. It is now theoretically possible to use a cell phone to call anywhere in the world via the INMARSAT (International Maritime Satellite) service. This system can support direct-dial telephone, telex, fax and data connection and already is serving some 10,000 users; covering oil tankers, luxury yachts and passenger liners.

BT is also now offering a direct-call service from ship to shore. Until recently such calls had to be made through an operator on shore. Unlike cellular radio which has a range of about 25 miles, the system can operate up to 200 miles on MF and 40 miles on VHF, connecting directly to the ship's radio.

Somewhat closer to home, P&O Ferries is investing nearly £4m in a new reservation system, again based on Digital Equipment hardware. This will link the Dover head office to other ports and offices proving a real-time reservation service based on Viewdata and EDI (electronic data interchange). High tech it seems is well afloat at P&O.

All Aboard

Seeing is believing they say. 'Electronics – The Maplin Magazine' is providing readers with the chance to sample the P&O shipboard life style for themselves. Voted incidentally, the 'Favourite Ferry Operator' by a national newspaper. Just answer the following questions, and send your answers on a post card to 'P&O Ferry Contest, The Editor, Electronics – The Maplin Magazine, P.O. Box 3, Rayleigh, Essex, SS6 8LR.' The first three correct entries drawn out of the editor's hat (which thanks to the popularity of his amazing prize offers is rapidly wearing out) will win the following star prizes:

First prize. Return tickets Dover/Calais for car and four passengers. (Worth up to £278.)

Second and Third Prize. Return Dover/Calais for car and two passengers. (Worth up to £224.)

So hurry, the contest closes 4th March 1991.

Audio-Frequency Induction Loop Systems

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

Part 3 – Bigger and Better Systems

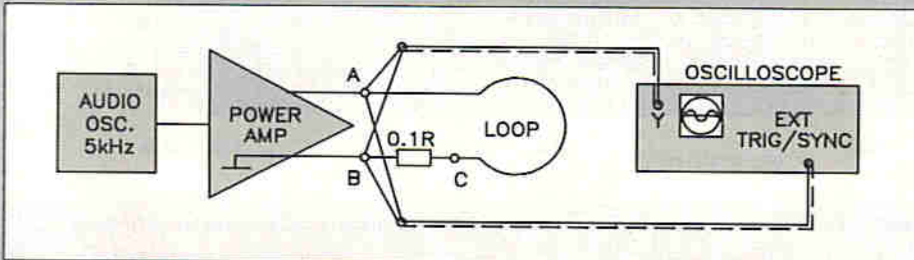


Figure 14a. Arrangement for measuring the phase angle between loop voltage and current with an oscilloscope.

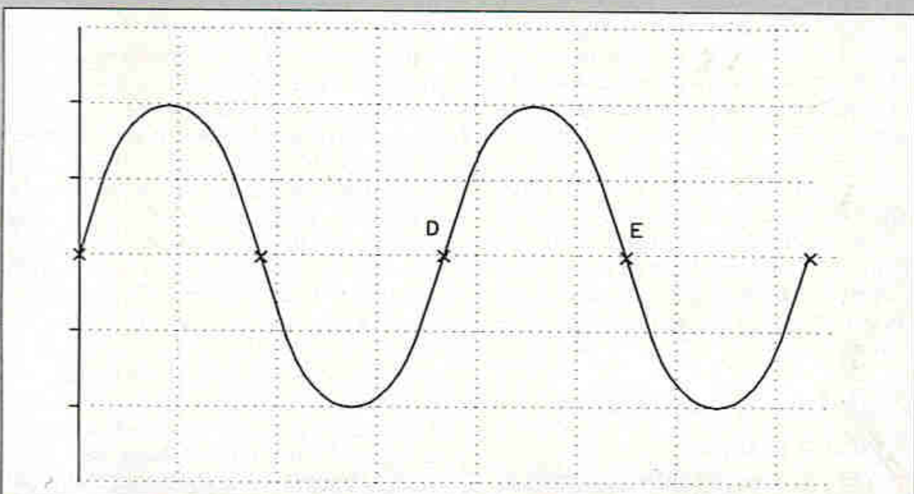


Figure 14b. Voltage waveform display with zero crossings marked.

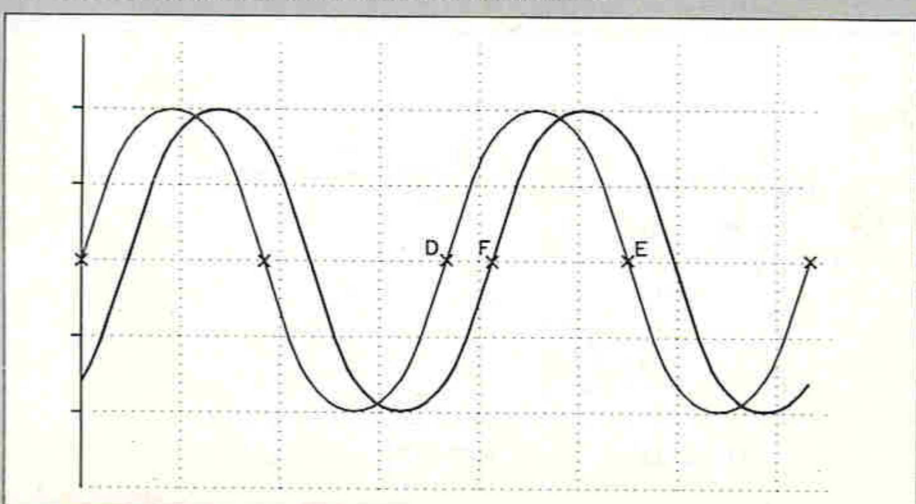


Figure 14c. Current waveform display (with voltage waveform display in the background), showing zero crossings, and phase-shift DF.

Re-Cap

We are at Part 3 now, so new readers will need to order both Issues 39 and 40 of 'the mag.' in order to get the full treatment. Meanwhile, the story so far.

Most hearing-aids are fitted with a 'telecoil', originally so that it would pick up the audio frequency magnetic field generated by the earpiece of the old-type telephones. This coil can also pick up the magnetic field generated by a loop of wire arranged round a room, and connected to the output of an amplifier. Thus signals from microphones, radio, TV or anything else can be sent straight into the hearing-aid user's ear, without disturbing other people and giving much better results for the hard-of-hearing person.

How to Feed Your Loop

There are said to be two different ways of feeding the loop: voltage drive, which uses an ordinary amplifier (see Part 2), and current-drive, which uses a special amplifier with a high output source impedance, and is said to be better. While this is not entirely a fairy-tale, we shall see this time that the matter is not so clear-cut. Not only is it possible to get poor results with a current-drive amplifier, if you do not understand what you are about, but it is also perfectly possible to design entirely satisfactory voltage-driven loop systems (even with multi-turn loops!), and to design an amplifier which voltage-drives some loops and current-drives others! I propose to call such amplifiers 'intermediate-drive' amplifiers, because most of the apparently better terms (such as 'hybrid amplifier') seem to have been used already for other purposes.

It should be carefully noted that the use of current or intermediate drive eliminates the natural high-frequency roll-off which is inherent in voltage-drive systems. Where these techniques are employed, therefore, a low-pass filter, preferably having a response −3dB at 5 kHz or thereabouts, should be included in the amplifier chain. This will not, however, prevent harmonic currents, generated through overloading at the amplifier output, from flowing in the loop and potentially causing interference to other

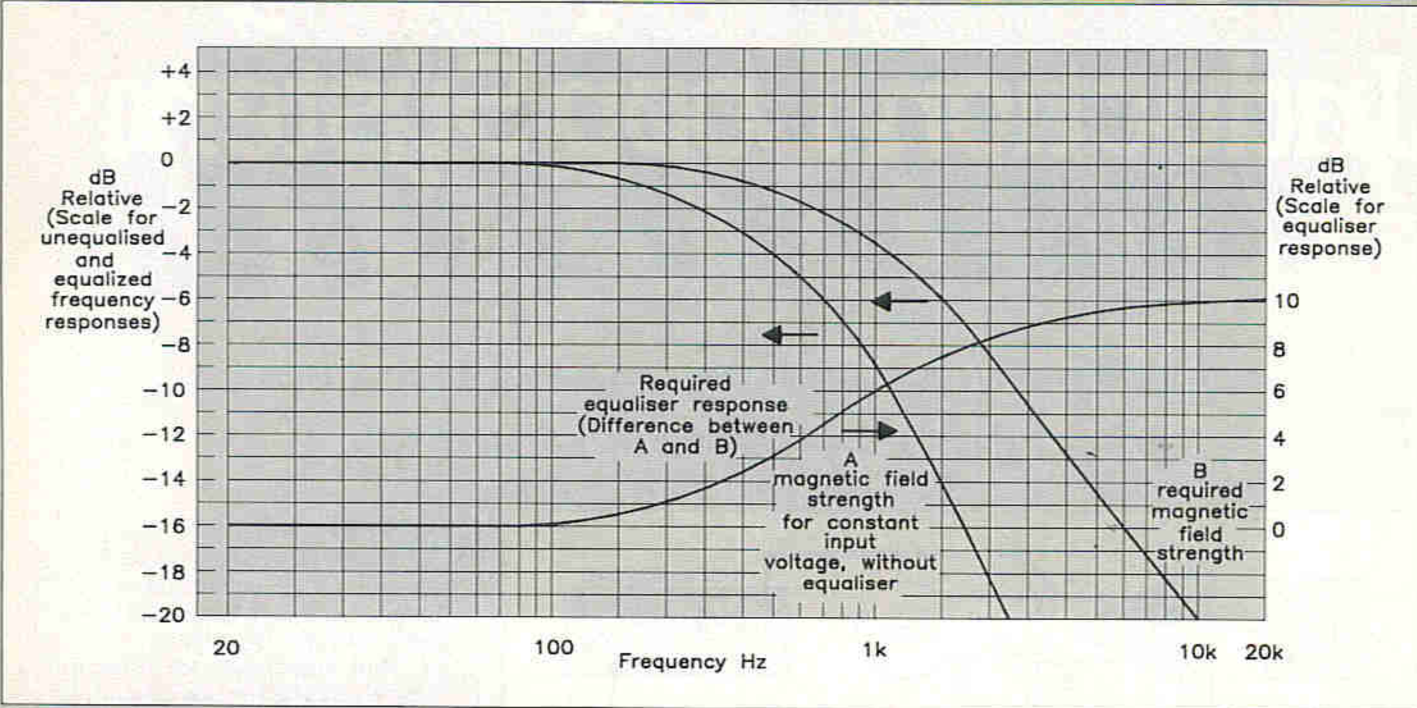


Figure 15. Frequency response of the magnetic field strength of a loop requiring equalising, the target frequency response and the resulting frequency response required for the equaliser.

equipment. Great care is therefore necessary, to ensure that overloading cannot occur under any conditions of use.

Simple 'Series Resistance' Technique

In Part 2, I explained a way of using a voltage-drive amplifier with a loop made of wire too thick to obtain the necessary 5kHz bandwidth: a rather more sophisticated way than what is a perfectly valid, if somewhat crude, 'series resistor' technique. This consists of simply connecting a (likely to be high-wattage) resistor in series with the loop, equal in value to the reactance of the loop inductance at 5kHz minus the actual loop resistance. The cleverer technique, which permits the use of a rather less powerful amplifier, uses a capacitor-resistor equaliser between the amplifier and the loop, quite a convenient place to put it.

To analyse the series resistor technique, we go back to the basic equations derived (with full justification from first principles where appropriate, so you can rely on their theoretical correctness) in Part 1. The inductance L of a rectangular loop a × b metres, made of copper wire of diameter d millimetres is:

$$L = 4(a + b)\ \mu H,$$

so that the reactance at 5kHz is:

$$X = 4 \times 10^4\ \pi(a + b)\ \Omega$$

and the resistance is

$$R = 18{\cdot}6 \times 10^{-3} \times 2(a + b)/(\pi d^2/4)\ \Omega$$

Alternatively, if you know the conductor AREA in mm^2 instead of the diameter, e.g. if you want to use $1mm^2$ house wiring cable, you can just insert it into the above equation in place of $(\pi d^2/4)$. Or you could use the measured value of resistance R: the DC resistance is quite good enough. The required series resistance is then equal to X – R. If you actually want to measure the inductance of the loop, this is quite difficult without a special bridge. Instead, it is easier to use a power engineer's technique: measure the resistance R and the phase angle θ between the voltage and current: X is then simply R tanθ. Appendix 1 and Figure 14 show how to use an oscilloscope to measure the phase angle: this technique is much simpler, if less elegant, than using Lissajou's ellipse.

Neck Loops and Ticket Office Systems

The series resistor technique is the one to use for a simple neck-loop. Fifteen turns of 7/0·2 insulated wire to make a 300mm diameter coil has very little resistance but about 8ohms of inductive reactance at 5kHz. With an 8Ω resistor in series, this loop can be fed from the loudspeaker output socket of a TV, radio or cassette recorder, and only needs a few tens of milliwatts drive. With a 4Ω resistor in series, it can be driven by the loop amplifier described in Part 2. To ensure that Grandma (the name I use instead of the pompous 'hearing-aid user') does not garotte herself if she forgets that she is wearing the neck-loop, put a pull-apart connector (e.g. HF80B/HF83E) in the connecting lead, near where it joins the loop. Such loops are also available commercially, and may also be fitted into cushions or under the seat of a chair, although they may be intended for current drive and thus do not have the series resistor built in. A similar arrangement can be used for a 'ticket-office system', as used in banks, booking offices and indeed

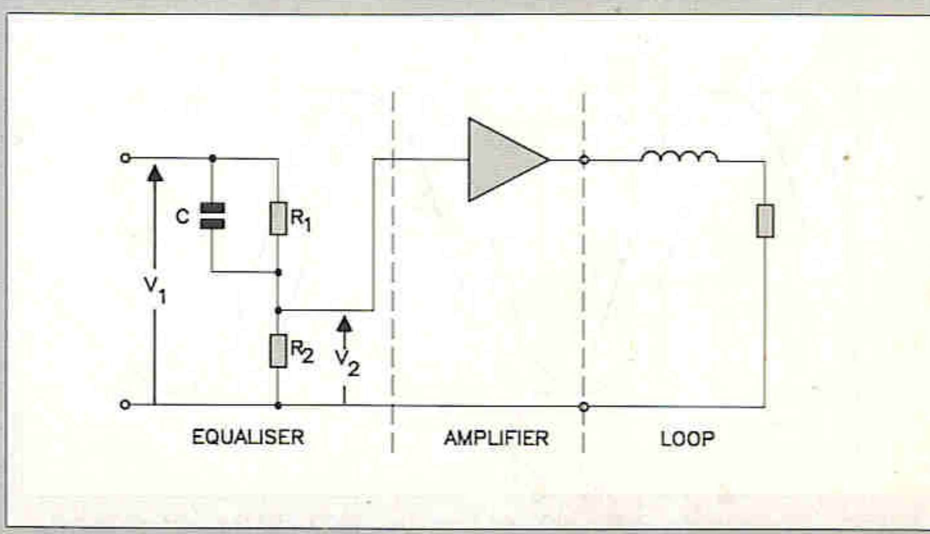


Figure 16. Passive low-level equaliser.

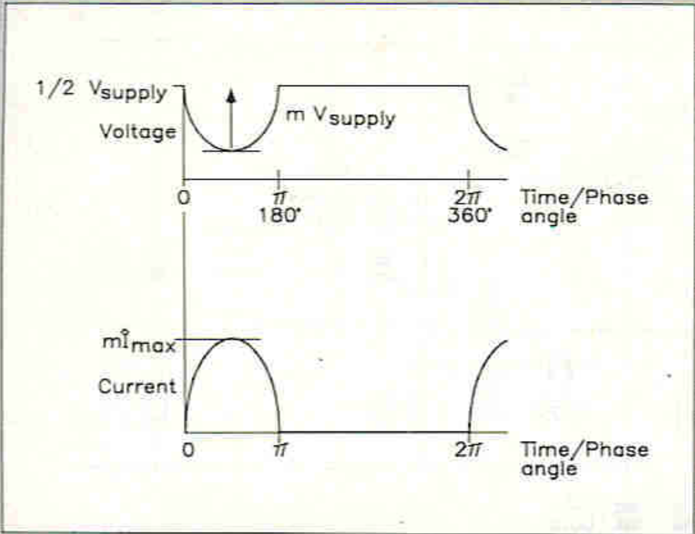


Figure 17a. Waveforms of the voltage across, and current through, the active device connected to the positive supply rail of a push-pull Class B stage with resistive load.

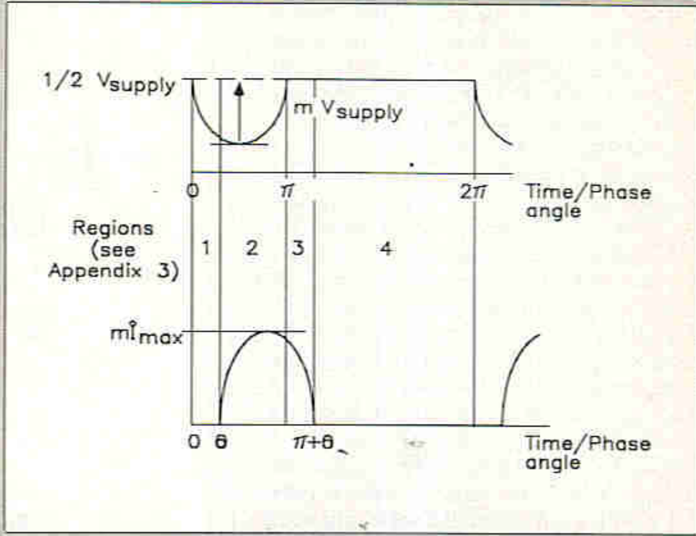


Figure 17b. Waveforms as for Figure 17a but with partly inductive load. For partly capacitive load, the current waveform is displaced to the left instead of to the right.

anywhere that two people need to communicate and one of them may have a hearing problem.

Voltage-Driven Loop with Low-Level Equaliser

Another way of looking at the high-level equaliser circuit is to say that the components in series with the amplifier output convert it into a current-drive amplifier! Indeed, this cannot be denied, for the effect is precisely that the loop current is kept constant to a far higher frequency than would be the case without the equaliser: a 'conventional' current-drive amplifier does no more.

It is fairly obvious that the same equalisation (but not current drive) could be achieved at the much lower signal levels at the amplifier input, or inside the pre-amplifier. What is needed is a 'step-network', a circuit that gives precisely the correct amount of treble-boost to extend the frequency response to 5kHz, (see Figure 15) without producing a peak or extending the response too far, so as to risk causing interference with other equipment and/or overloading of the amplifier itself. This latter point should be clearly understood; if you make the bandwidth wider than necessary, you must use a 'bigger' amplifier to drive the loop at the higher frequencies without overloading. This is because, if the amplifier is driven too hard by unnecessary high-frequency signals, it will also distort all the useful, lower-frequency signals that are going through at the same time.

Low-Level Equaliser

It isn't quite as simple as it might appear to produce precisely the correct equalisation. You only need two resistors and a capacitor, as shown in Figure 16, but you must choose the right values! The underlying, only slightly hairy mathematics appears in Appendix 2, and results in the choice of one of the three component values being open, and that choice then fixes the other two values. Usually, it would be the capacitor value that is chosen first (for convenience and because variable capacitors of the required values are rare and very expensive!), and the two resistors made preset adjustments, because they have to be set up for each individual size of loop. Because their sum is not constant, a single pot. cannot be used in this circuit, and because of the individual setting-up needed, this technique is not widely used. Nevertheless, there is no reason why it should not work properly if designed and set up correctly.

Power Dissipation in Class B Output Stages with Reactive Loads

I was not going to go into this subject, but since it has been suggested to me that it is another area of confusion, here goes!

Textbooks analyse the operation of Class B output stages (i.e. for audio, anyway, push-pull stages in which each half conducts for only one half of the complete cycle) for resistive loads only, and derive equations for efficiency as a function of signal level and the signal level at which the power dissipated in the output devices (bipolars, FETs or valves/tubes, it doesn't make much difference) is a maximum. However, induction loops, unless they use the high level equaliser technique explained in Part 2 and above, present what may be a predominantly inductive load to the amplifier. Loudspeakers, except certain high-fidelity designs (e.g. some KEF models) also present a reactive load to the amplifier, and, due to the action of crossover networks, this may be capacitive or inductive. So the following reasoning also applies to conventional sound systems as well as induction loop systems.

The low power dissipation and high efficiency of the Class B output stage depends on the voltage across each output device being high when the current is low,

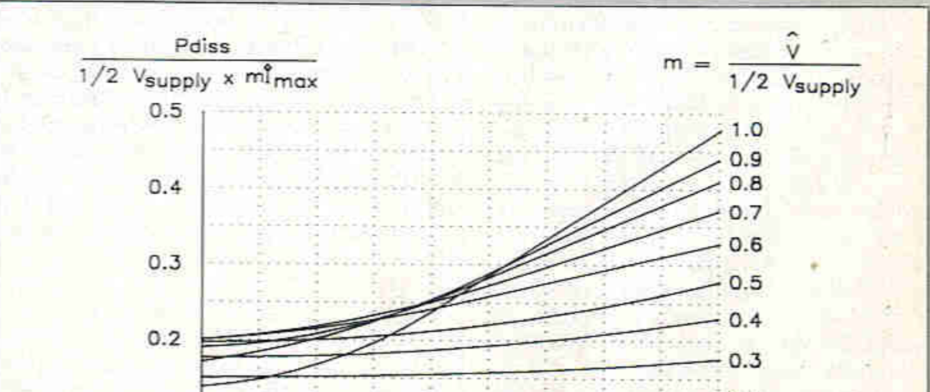


Figure 18. Total power dissipated in the output devices of a Class B push-pull amplifier having a load impedance of constant magnitude, as a function of the load phase angle. The parameter m is the 'drive level', expressed as actual peak output voltage divided by maximum possible peak output voltage.

and low when the current is high (Figure 17a). When the load is reactive, the phase relationship between the voltage and current is different (Figure 17b), and this results in more power being dissipated in the output devices, which therefore get hotter. It is possible to calculate what happens (see Appendix 3), and the results are shown graphically in Figure 18. Provided the signals are similar to speech, with a maximum-to-average ratio of 15dB or so (i.e. factor $m = 0{\cdot}177$ in Appendix 3), it is not necessary to be concerned about the extra heat, but this is far from true if you want to pass sine-wave signals at maximum level through the system for any length of time (whatever for?). You then need 2·5 times as much heat sinking (i.e. one quarter of the thermal resistance) with a pure inductive (or capacitive: the same equations work for both) load as for a resistive load, which usually represents a big difference in size, cost and weight.

It is important to realise that the output stage does not 'know' whether the amplifier is a voltage-drive amplifier or a current-drive amplifier: there is absolutely no difference in power dissipation if both are working under the same conditions. The one configuration that gives better results (less heating) is the high-level equaliser, because this converts the inductive load of the loop into a more nearly resistive load, at least up to the chosen band-limit frequency (or higher, if you use a higher frequency in the relevant equations in Part 2).

Pure Current-Drive Amplifier

In Part 2, I described a voltage-drive amplifier for a small loop system, based on the TBA810 IC. The prospect of trying to make a current-drive amplifier, based on the same device, stable under all load conditions did not look attractive. However, it is possible to make a current-drive amplifier based on the TDA2030 (WQ67X). I should emphasise that *this is only an experimental design* and not a finalised project. The circuit is shown in Figure 19, and does *not* fit well onto the Maplin 15W amplifier kit PCB, because that uses a single supply rail. This design uses ±9V rails, and the load has to be DC coupled, so DC offset can be a real problem if the load resistance is high. The 1kΩ resistor across the output helps to minimise this. Without it, the amplifier goes bananas if the loop is disconnected, because its feedback disappears and it has over 90dB of gain under those conditions.

The pure current drive is obtained by applying negative feedback proportional to the output current, derived from the voltage drop across R6. The manufacturer of the TDA2030 says that the closed-loop voltage gain (pin 4 to pin 1) should not be less than 24dB, presumably to avoid instability, so for a minimum loop resistance of 0·5Ω, R6 should be, say, 0·1Ω, giving 15·5dB attenuation, and R2 should then form a 10dB attenuator (to give

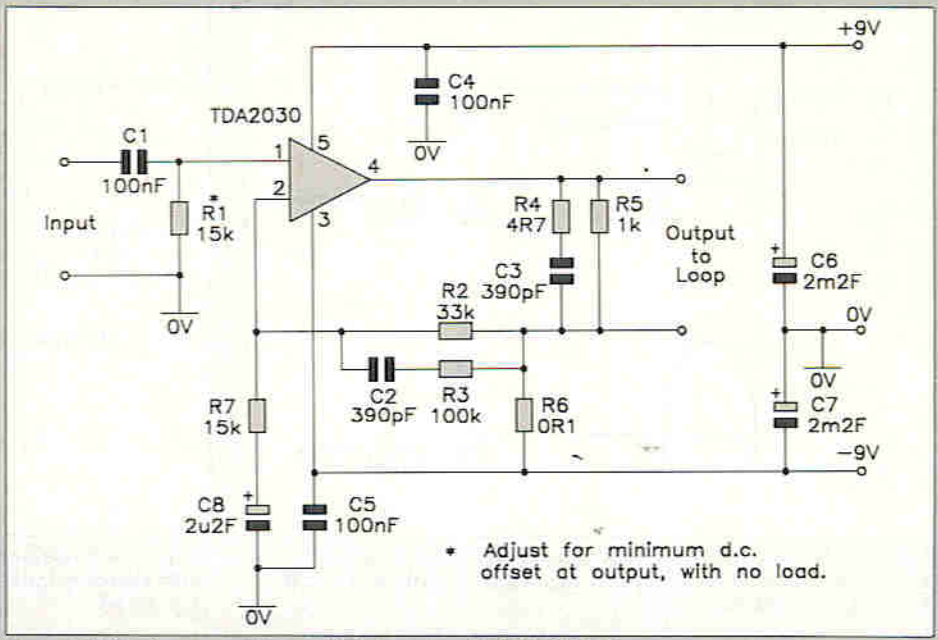


Figure 19. 'Pure' current-drive amplifier based on the TDA2030 IC.

some safety margin) with R7, as shown. A lower minimum load resistance requires more attenuation in the R2/R7 divider and/or a lower value of current-sensing resistor R6. This amplifier will deliver 2·5A into any load requiring less than about 8V peak to drive that current, i.e. 2·3Ω, and this is a clue as to one way to get into difficulties with a current-drive amplifier. If your loop impedance is too high, especially at 5kHz, the amplifier will 'run out of volts' and be unable to sustain the required current, and thereby its reputation as a 'constant current source'.

We can calculate the voltage required by a loop as follows. It is obvious that fewer volts are required for a loop that has as low a resistance as possible, because any extra resistance requires extra volts, above those required to drive the necessary current through the inductive reactance (which is fixed by the loop dimensions and cannot be reduced). However, as explained above, there may be a lower limit on loop resistance, dictated by the need to ensure that the amplifier is not given too much feedback. It is nevertheless very likely that a practicable size of loop conductor can be chosen, so that the inductive reactance at 5kHz greatly exceeds the resistance, which can thus be neglected. The current required is given by the equation from Part 1:

$$I = \pi abH_o/2d,$$

where a and b are the sides of the loop in metres, H_o is the required magnetic field strength (after allowing for the reduction of field strength with listening height – see Part 1), and d is the diagonal measurement of the loop, $\sqrt{(a^2 + b^2)}$. The voltage required to produce 3dB less than this current at the upper band-limit frequency in the inductive reactance of the loop is:

$$V = \sqrt{2} \times \pi f_c \times 4 \times 10^{-6}\,(a + b) \times \pi abH_o/2d$$

For f_c = 5kHz and $H_o = 0{\cdot}56$ Am^{-1}, this simplifies to:

$$V = 0{\cdot}078ab(a + b)/\sqrt{(a^2 + b^2)} \text{ volts}$$

Note that the voltage depends in a complicated way on the dimensions of the loop: it isn't simply proportional to the area, for instance. However, for a square loop *only* (a = b), it is proportional to the area:

$$V = 0{\cdot}11a^2 \text{ volts}$$

For a loop 20m by 20m, for example, V = 44V. Since the current I = 12·44A for this loop, it appears that we need an amplifier 'power rating' of 547W for this loop! It is, however, possible to use a more modest amplifier by taking advantage of the fact that the spectra of most programme signals fall at high frequencies. The permissible extent of this allowance, without risk of amplifier overload, is complicated by having to take into account any treble-lift in the microphone frequency response, and any other relevant factors. It is difficult to give more than a guide figure, but 7dB reduction may be permissible, and this implies a voltage of 18V and a 'power rating' of 220W, a worthwhile reduction. Note that the 'power' is not reduced by 7dB, because the need to supply 12·44A at low frequencies still applies. A further reduction could be achieved by including a compressor in the pre-amplifier, so as to reduce the maximum-to-average ratio of the signals from about 15dB to, say, 9dB (any more compression would not sound very good).

Output Source Impedance of a Current-Drive Amplifier

This is a concept which causes great confusion. Figure 20 may help to explain that *any* source of signals may be regarded as either a voltage generator V_s volts (of zero impedance) in series with an impedance Z_s (called the Thevenin equivalent circuit), or as a current generator I_s amps (of infinite impedance) in parallel with the same impedance Z_s (called the Norton equivalent circuit). V_s, I_s and Z_s are related by Ohm's Law:

$$V_s = I_s Z_s$$

If the source of signals is an amplifier, Z_s is called the 'output source impedance', and is something totally different from the load impedance Z_L , which is what you connect to the output terminals externally. For an ordinary audio amplifier Z_s is typically 0·1Ω or less. For the TDA2030 current-drive amplifier configuration, the output source impedance can be shown to be:

$$Z_s = AR_6 R_7 / (R_2 + R_7),$$

where A is the open-loop gain of the TDA2030: the data sheet says this is typically 90dB (= 31,623 times!), and it could possibly be twice this for some samples. For the values given, Z_s = 938Ω. The 1kΩ resistor across the output appears in parallel with this, giving an effective source impedance of 484Ω. Another version of this circuit that I have tested, gives a 20 times higher value. Since we are dealing with load impedances of the order of 3Ω or less, there is no need for such a high source impedance (although it may do no harm). For example, if the loop resistance is 0·5Ω, and the inductance is 100μH (i.e. a loop of 50m perimeter), the loop impedance is 3·2Ω at 5kHz. If the current were set at 1A at a low frequency, it would fall to only 0·9945A at 5kHz!

The claimed advantage of current-drive amplifiers is that you don't have to be so careful about the size of loop conductor, and it is certainly true that you are not restricted to 7/0·2 or thinner wire, as you are for a directly-connected voltage-driven loop (although not, of course, if you use a series resistor or a high or low-level equaliser). However, the amplifier will not be very efficient at low frequencies if the loop resistance is as low as the value of the current-sensing resistor, and, as we have seen above, a minimum load resistance may have to be specified in order not to violate minimum closed loop gain conditions imposed by the active device manufacturer. If there is a need to put high-level continuous tones through the system (perhaps for alarm signals), the loop resistance should be kept up to at least half the value of the inductive reactance at 5kHz, so as to limit the extra heating (Figure 18).

Amplifiers with Combined Voltage and Current Feedback

We have seen above that pure current feedback, giving pure current drive to the loop, drives the loop from an unnecessarily

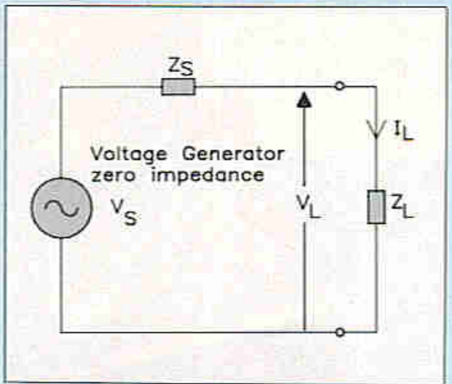


Figure 20a. Thevenin equivalent circuit of the output of an amplifier (or anything else). Z_s is the output source impedance and Z_L is the load impedance.

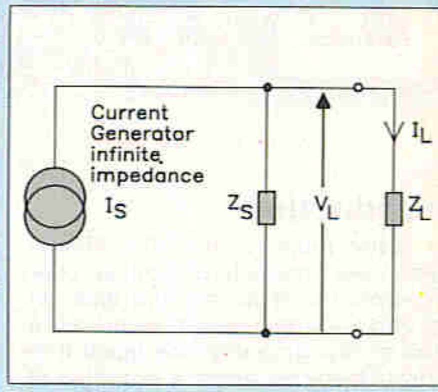


Figure 20b. Norton equivalent circuit, with identical characteristics to Figure 20a.

high source impedance, and perhaps requires care not to violate the minimum loop resistance requirement for stable operation. An amplifier with both voltage and current feedback can be designed to have almost any value of output source impedance that seems desirable, and may be more tolerant of the exact value of load impedance. It is thus possible to design for nearly current-drive conditions (output source impedance about 10 times the loop impedance, instead of the 100 or more times typical of pure current feedback), or for 'intermediate-drive' conditions, where the amplifier output source impedance is in the region of 2Ω, so that it nearly current-drives low-impedance loops (e.g. 0·5Ω) and nearly voltage-drives high-impedance loops (e.g. 8Ω).

The typical feedback configuration for this type of amplifier is shown in Figure 21.

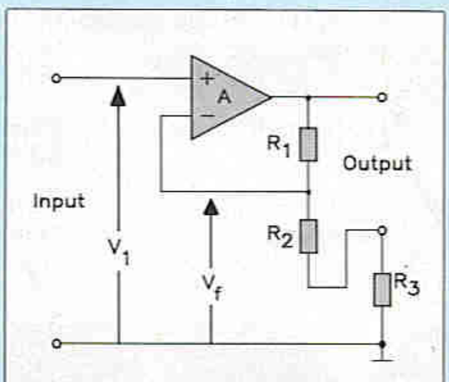


Figure 21. Typical combined voltage and current feedback configuration.

R_1 and R_2 provide the voltage feedback, while the voltage across R_3, proportional to the loop current, is added in series with R_2 as current feedback. The output source impedance of such an amplifier, including the physical resistor R_3 is $R_3 \times (R_1 + R_2)/R_2$, if the open-loop gain A of the amplifier is much larger than R_1/R_2. It is possible to design for a given sensitivity and a given output source impedance simultaneously, and still choose the value of either R_1 or R_2 arbitrarily. For example, if an amplifier is required to have an input voltage of 1V for full output, deliver 7A maximum and 20V maximum, and we need an output source impedance of 10Ω, i.e. near current drive for most loops, we get:

$$V_1 \approx V_f = 7R_3 + 20R_2 / (R_1 + R_2) = 1$$ (volt),

since the open-loop voltage gain A is assumed to be very large. Also:

$$R_3 (R_1 + R_2) / R_2 = 10 \text{ (ohms)}$$

From the first equation,

$$R_2/(R_1 + R_2) = (1 - 7R_3)/20.$$

Turning this upside down and putting it into the second equation:

$$20R_3/(1 - 7R_3) = 10$$

giving R_3 = 0·11Ω (three resistors of 0·33Ω in parallel). Substituting in the second equation, and choosing R_2 = 1kΩ for convenience, R_1 = 89kΩ.

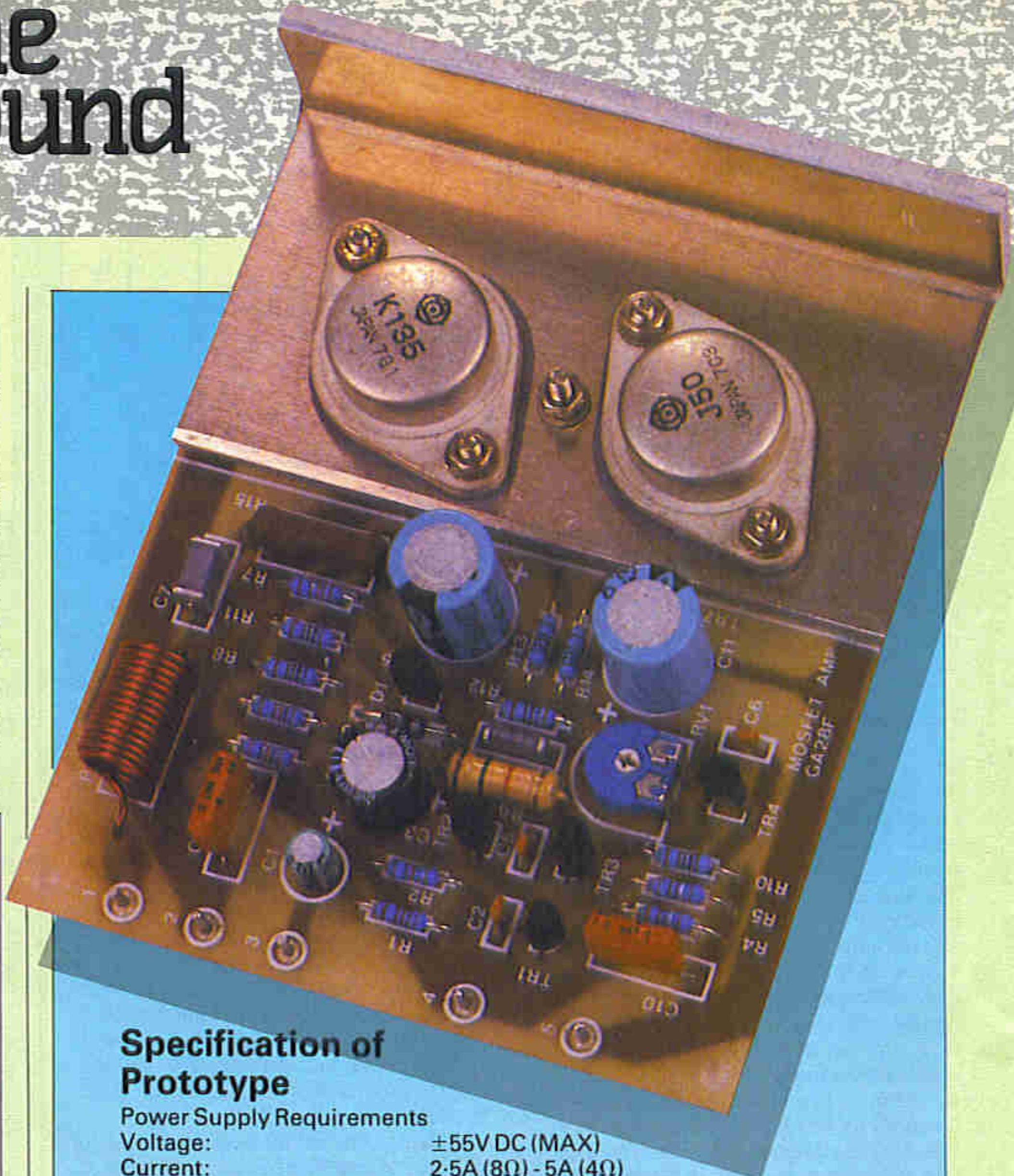
An exactly similar calculation, for the same input voltage of 1V for full output, but a source impedance of 3Ω, giving intermediate drive conditions, results in R_3 = 0·073Ω (wind it yourself!) and, if R_2 = 1kΩ still, R_1 = 40kΩ.

A Practical Intermediate-Drive Amplifier

To be useful for a loop system in a church, for example, quite a powerful amplifier is necessary. I have been looking at a design based on the Maplin 50W (discrete) amplifier LW35Q, because this is a very high-quality design and is capable of delivering far more current than the 4·24A implied by the specification of 72W into a 4Ω load. (This is essential for a high-quality audio amplifier because, under certain conditions, loudspeakers can draw unexpectedly large currents.) The basic design, *which is still experimental,* is shown in Figure 22. Combined voltage and current feedback has been applied, and the open-loop bandwidth adjusted by increasing C_3 so that stability is maintained. However, in order to be useful, this final

Continued on page 70.

2nd Time Around



Introduction

Many projects from the Maplin range have proved to be popular over the years. However, modern technology and electronic components have a habit of changing with the result that some of these projects are in danger of becoming obsolete as the originally specified components become unavailable or standards change. In order for some of the more popular projects to remain available, updates and improvements are necessary, and to this end these projects are being reviewed in the series "2nd Time Around". This time it is the turn of the MOSFET Amplifier.

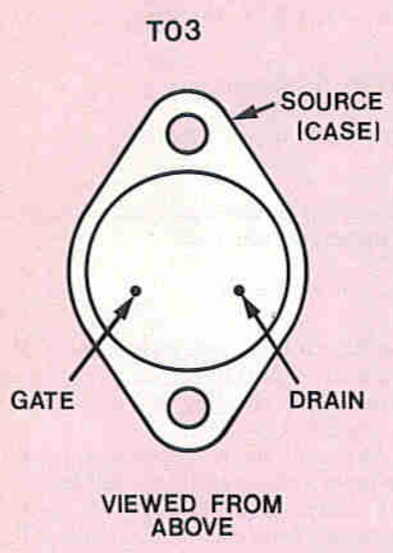


Figure 1. Power MOSFET package.

Specification of Prototype

Power Supply Requirements	
Voltage:	±55V DC (MAX)
Current:	2·5A (8Ω) - 5A (4Ω)
Power Output (1kHz continuous sine wave)	
Rating:	100W RMS into 8Ω 150W RMS into 4Ω (absolute maximum)
Frequency Response:	20Hz to 40kHz
T.H.D.:	0·01% (at 1kHz)
Input Impedance:	47kΩ
Sensitivity:	860mV RMS input (2·43V Pk - Pk) for rated output

MOSFET AMPLIFIER

by Dave Goodman

Ancient History

The Maplin MOSFET Amplifier was originally developed for use as a guitar amp in the late seventies and first saw the light of day with the 75W Combo Amplifier project ('Electronics' Issue 1). Shortly afterwards – by popular demand – the power amplifier section from the project was published in 'Electronics and Music Maker magazine' and also in the Best of E&MM projects book and has remained one of our biggest selling projects over the last decade!

The amplifier was not intended to reflect a state-of-the-art Hi-Fi design as the requirement was for a rugged, easy to build project that would offer good, reliable performance and – to quote our early advertising – be "virtually bomb-proof like the best valve amps". Journalistic licence maybe, but the enormous success of this project would certainly substantiate this claim!

The MOSFET

Figure 1 shows the terminal connections for a MOSFET, viewed from *above* the TO3 package. The Source terminal, incidentally, is the metal package itself and connections to it are made through both of the case mounting holes. Thermally, the MOSFET has an advantage over the bi-polar transistor. As a bi-polar transistor heats up in use, the collector current increases due to the positive temperature coefficient of the device. If the temperature rise were allowed to continue then thermal runaway would ensue and the transistor could be destroyed. A MOSFET however exhibits a negative temperature coefficient. As the device heats up in use the Drain-Source current decreases (due to increasing internal resistance), the device temperature will also reduce in turn and the Drain-Source current will then rise again. Used in a power amplifier this self regulating effect can be desirable as it offers a high degree of immunity from misuse – or abuse according to your musical taste perhaps?

The symbols given for N and P type MOSFETs in Figure 2 relate to the Gate voltage and Drain current transfer characteristics and show the MOSFET to be an enhancement type.

Figure 3 shows the output characteristics of typical MOSFET devices.

These particular qualities of the MOSFET allow for much simpler designs to be produced, as complex biasing and quiescent current compensation arrangements are not required, which is usually the case with bi-polar transistors. The typical Total Harmonic Distortion (T.H.D.) of the MOSFET is very low for output levels up to 50W. At higher frequencies and power levels approaching 100W the T.H.D. levels increase as can be seen in Figure 4, although these figures remain fairly insignificant in practical terms.

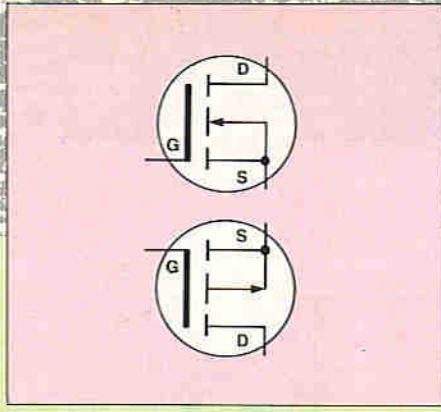


Figure 2. MOSFET symbols.

Circuit Description

The amplifier design originates from the late seventies, as previously mentioned and still remains virtually the same, except for a few minor improvements made to ease assembly and improve reliability. In the circuit

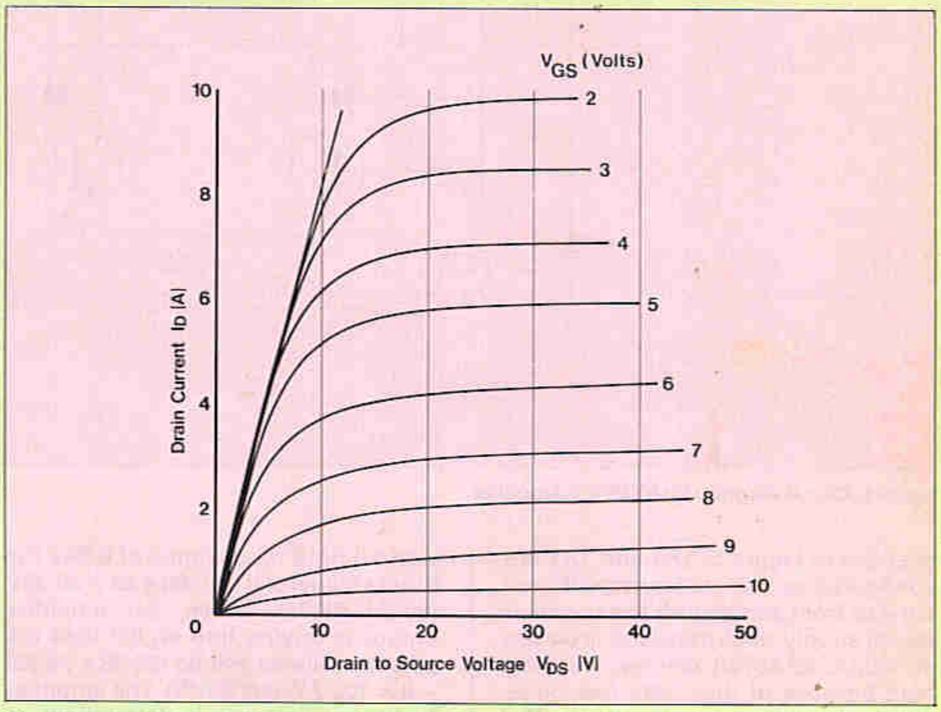


Figure 3. Typical output characteristics (2SK135).

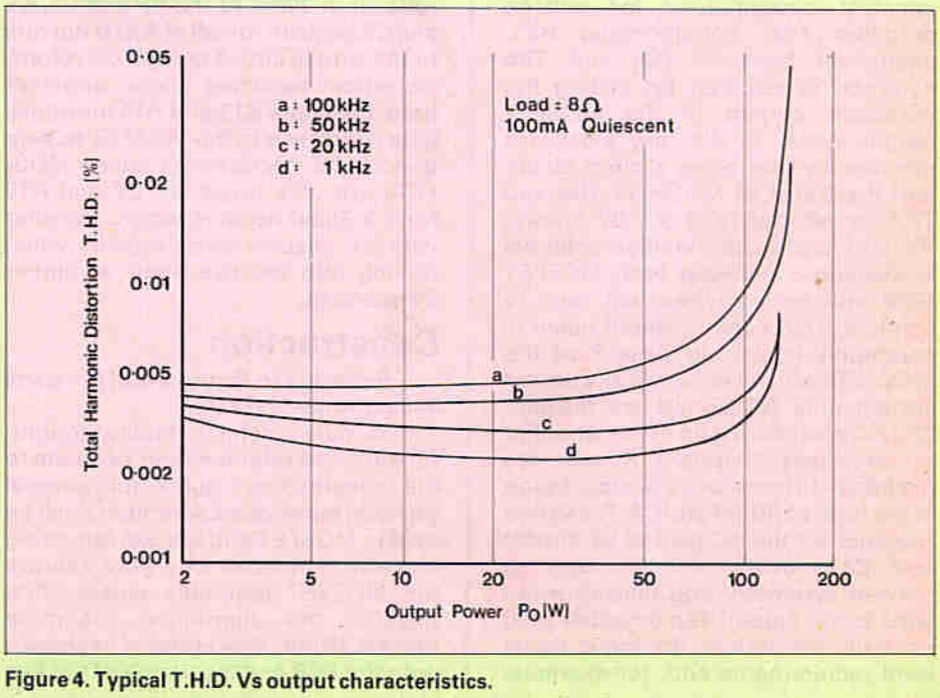


Figure 4. Typical T.H.D. Vs output characteristics.

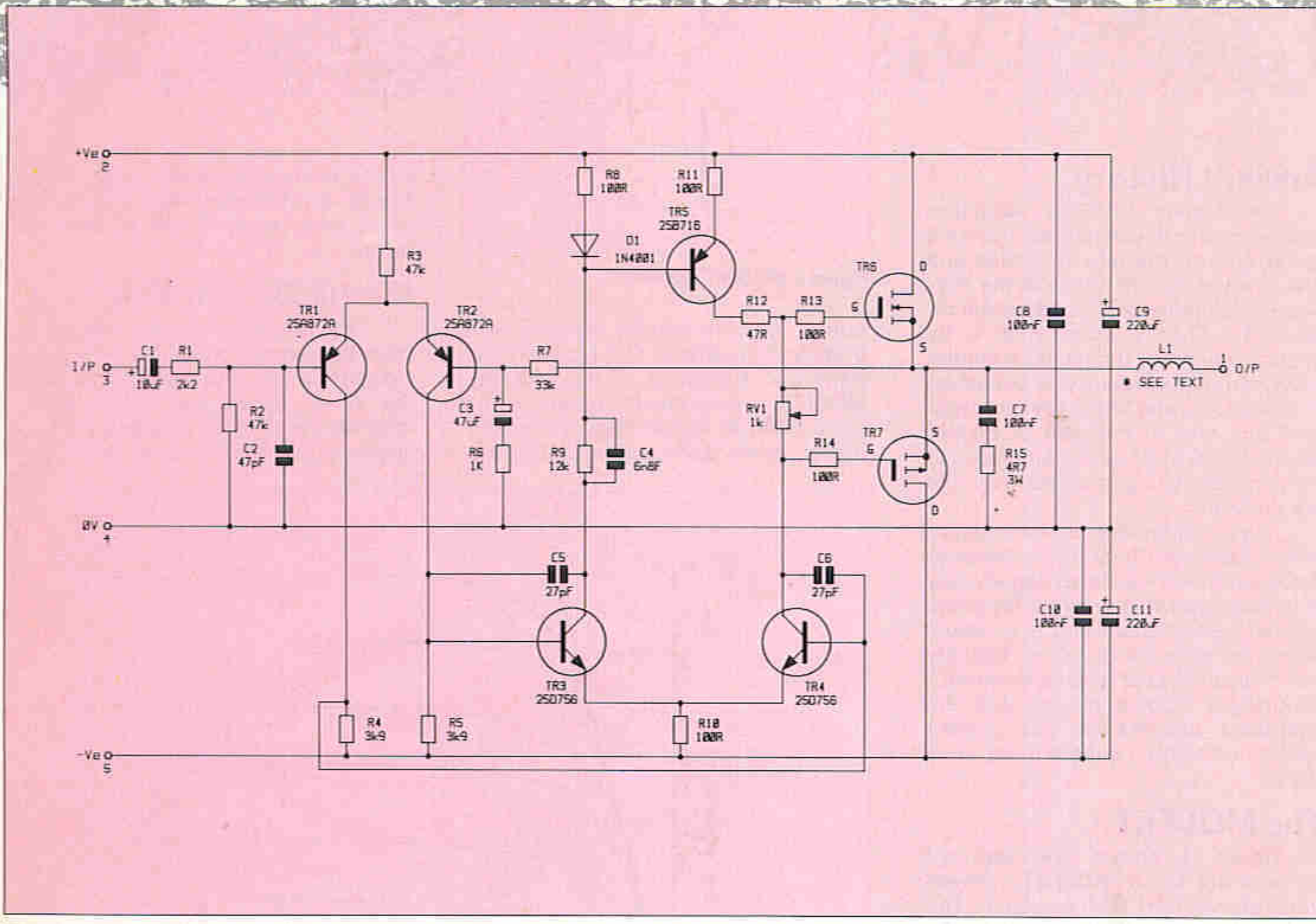


Figure 5. Circuit diagram for MOSFET Amplifier.

diagram of Figure 5, TR1 and TR2 are configured as the well known differential pair front end and for the specified power supply, each transistor is biased at 500μA. 2SA872A devices are used here because of their very low noise and high voltage specifications. The circuit around TR5 and D1 form the constant current load for voltage amplifier TR4. Potentiometer RV1, positioned between TR5 and TR4 collector, is required for setting the quiescent current in the MOSFET output stage. At the fully clockwise position RV1 becomes a short circuit and the Gates of MOSFETs TR6 and TR7 are effectively at 0V. By turning RV1 anti-clockwise a voltage potential is developed between each MOSFET Gate and both devices will start to conduct. This type of output stage is commonly known as class B as the MOSFETs will not generate any output current until AC signals are present. The AC open-loop gain of the amplifier is very high, therefore it becomes necessary to introduce a feedback loop in the form of R6, R7 and C3. These two resistors set the AC gain at 33 (times) and C3 provides DC blocking to prevent symmetry and biasing problems at the output. The amplifier gain naturally determines the input signal level requirements and, for example, with an RMS input signal of 0·86V the output signal will be 0·86 x 33 = 28·38V (80·2V Pk-Pk). When the amplifier output is driving into an 8Ω load the power available will be (28·38 x 28·38) ÷ 8 = 100·7 Watts (RMS). The amplifier frequency response is determined, at the LF end, by capacitors C1 and C3 and rolls off at 20Hz. At the HF end C2, C5 and C6 begin to roll off at 40kHz but due to the simple circuit design, waveform distortion becomes more apparent here. Resistors R13 and R14 introduce gate resistance to the MOSFET to help prevent HF oscillation – which MOSFETs are very prone to! C7 and R15 form a Zobel network which, together with L1, ensures good stability when driving into reactive loads at higher frequencies.

Construction

Referring to Figure 6 and the parts list assemble the PCB.

Module assembly is quite straightforward and reference can be made to the constructors' guide for general building techniques. Attention must be paid to MOSFET and bracket mounting and also to inductor L1. Figure 7 shows the MOSFET assembly details; first position the aluminium mounting bracket (Note: this is *not* a heatsink!) onto the PCB and insert one of the five 6BA bolts through the centre locating hole. Fit a 6BA washer and nut to the bolt, but before tightening the nut, ensure the bracket is positioned centrally over both MOSFET positions shown on the PCB legend. This is important – if the MOSFET terminals are to be prevented from shorting out onto the bracket. Place one silicon insulator pad onto each MOSFET and, after straightening any bent Gate or Drain terminals, fit the MOSFETs into their respective positions as shown. Finally, lock each device in place with two 6BA nuts, washers and bolts inserted from the PCB track side. Solder all four bolt heads onto the copper track to ensure good electrical connection. To make the inductor L1, first straighten out the 0·9mm enamelled copper wire, smoothing out the kinks and bends, and close-wind 15 complete turns using a pencil or plastic tube (ball-point pen) as a former. The former must be strong and between 8mm and 10mm in diameter and if wound neatly the coil produced should be not more than 15mm in length. Cut off excess wire and bend both end wires at right angles as shown in Figure 8; to fit into the PCB correctly, bend the two wires allowing for 23mm centre spacing. Scrape away the enamel from both wire ends then fit and solder L1 into the PCB. Note that R16 is printed on the legend but is not supplied or required. Resistor R9 may be a little large for the existing board holes, but will just fit okay. Thicken the track running from the Source (case) mounting bolt of TR6 to inductor L1, with plenty of molten solder. The track running between the remaining two Source bolt heads can also be treated in this way.

Testing

First ensure that all components have been correctly soldered onto the board and that all joints are sound. Clean off any excess flux with a suitable PCB solvent and inspect for shorts and 'whiskers'– most problems on this amplifier are caused by a lack of attention here! With a suitable test meter set to read ohms check for continuity between the mounting bracket and each MOSFET case, Drain and Gate terminal. Any connection between the MOSFETs and bracket will cause problems, so if a 'short' is found it will be necessary to strip down the MOSFET assembly to investigate the cause. Check between 0V pin 4 to +V pin 2 and 0V to −V pin 5; except for an initial 'kick' as the decoupling capacitors charge there should not be any

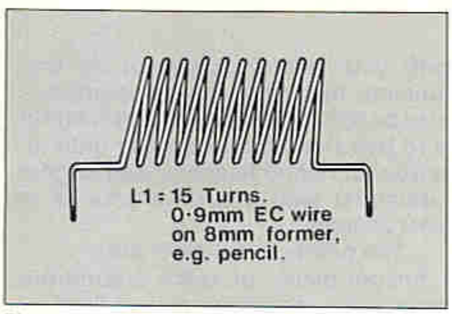


Figure 8. Making the inductor L1.

short circuits here either. Check for continuity between the output pin 1 and the MOSFET cases as well. Finally, with a small screwdriver or trimming tool adjust the wiper (arrow) on RV1 so that it points to the + symbol below R14.

Supply and Demand

A split rail supply is required for powering the amplifier and you will probably find that this item costs more than the amplifier itself! Figure 9 offers a suggested circuit for a PSU suitable for most requirements. You may also like to note that a full specification High Quality Power Supply module will be available as a kit in a future edition of 'Electronics' magazine. Toroidal transformer T1 (YZ23A) is an audio grade

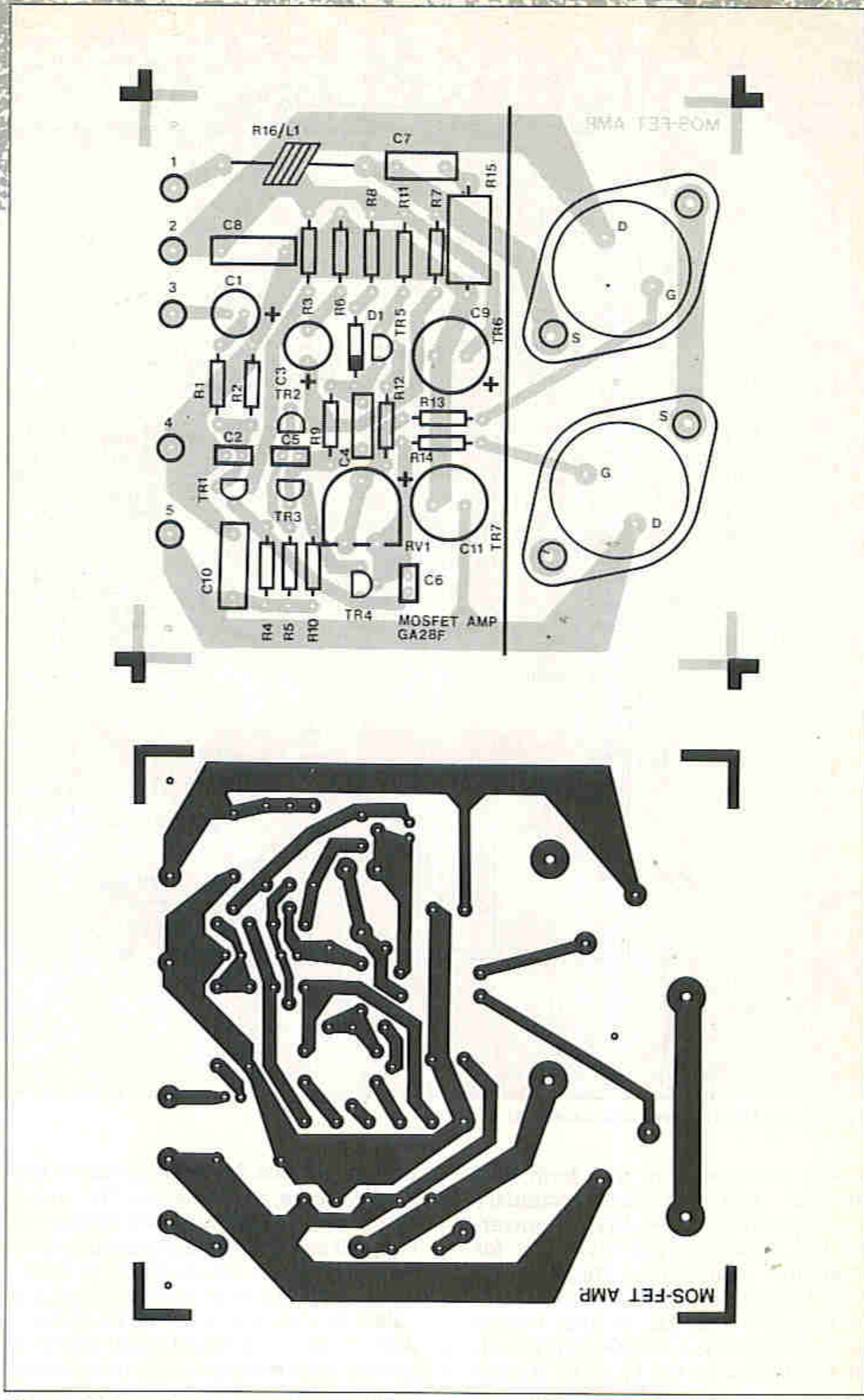


Figure 6. PCB overlay and legend.

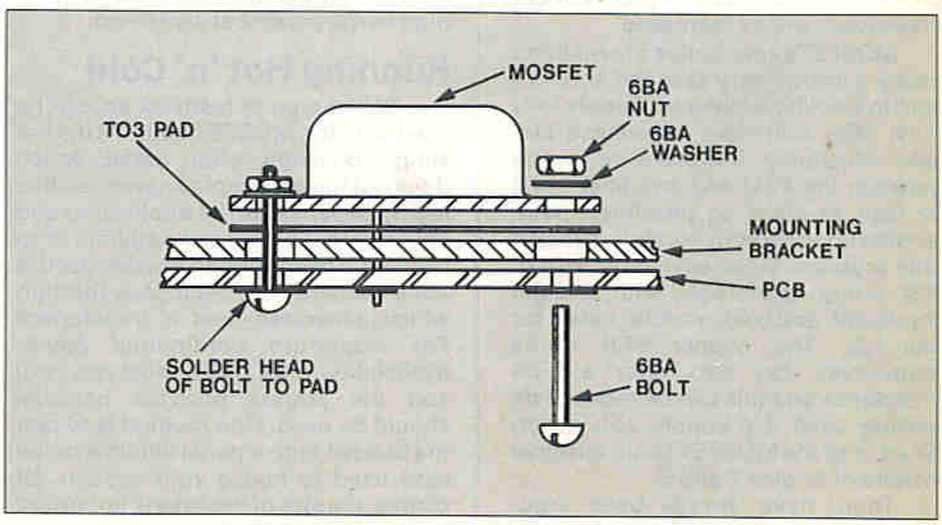


Figure 7. Method of mounting MOSFETs.

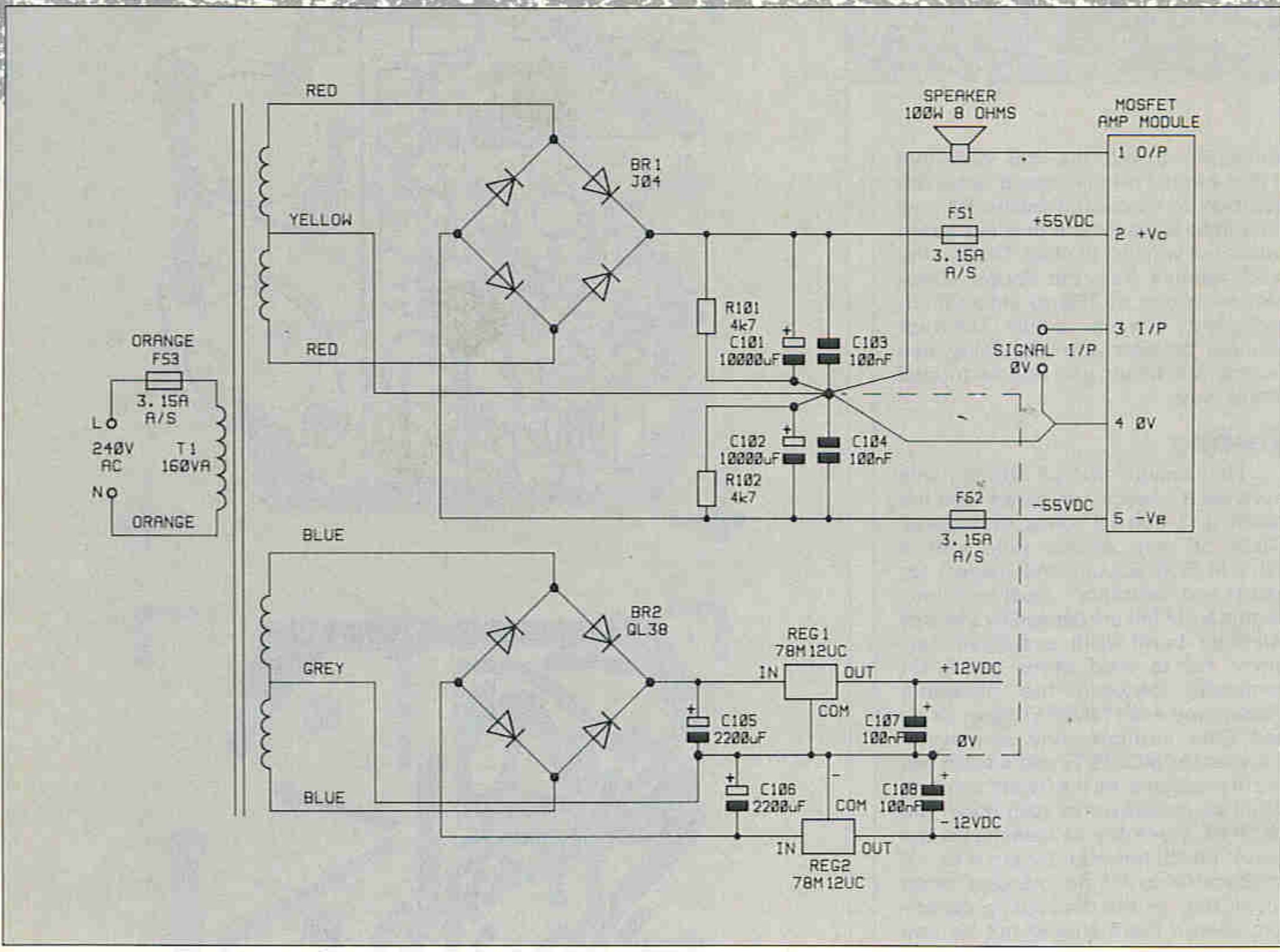


Figure 9. PSU and external connections.

device designed for use with this amplifier and has two secondary windings fitted: 39V-0-39V for powering the amplifier and 12V-0-12V for additional preamplifier stages if required. Once powered up the PSU will develop 55V - 58V DC on each supply rail and this is the ABSOLUTE MAXIMUM allowed for the MOSFET Amplifier. Whatever type of PSU is to be used DO NOT exceed the maximum voltage given as the risk of component breakdown will be increased.

MOSFETs are capable of switching heavy currents very fast and this can lead to stability problems. Supply rails must offer both low impedance and low inductance, therefore all wiring between the PSU and amplifier must be kept as short as possible – wire lengths up to 300mm normally present little problem. Use heavy duty wire of 30A rating, preferably with a solid conductor, and cooker cable is ideal for this job. The copper PCB tracks themselves can also offer a high inductance and this can be reduced by making each ±V supply connection direct onto the MOSFET Drain terminal instead of to pins 2 and 5.

There have always been arguments for and against fitting fuses in the supply rails. Much depends on the quality, type and reasons for using them. Anti-surge fuses are shown in Figure 9 as standard types are prone to 'pop out'. It is a good idea to fit lower value (0·6A) fuses when powering up a newly built amplifier for the first time – just in case. The transformer primary should also be fused – to protect the mains connecting cable. It is important to use Anti-Surge fuses (3A) as torroidal transformers draw a very high surge current at switch-on.

Running Hot 'n' Cold

"What type of heatsink should be used with the MOSFET amp?" This is a simple question, often asked, which does not have a simple answer; as this totally depends on the application and environment where the amplifier is to be used. The mounting bracket itself is *not* a heatsink, but the means through which generated heat is transferred. For maximum continuous power availability, a MOSFET must run cool and the largest possible heatsink should be used. One method is to bolt the bracket onto a panel within a metal case used to house your system. Of course, the size of the case is important – a small case may feel cool externally with your system powered up and running, but inside the temperatures may be 50°C or more! Another method is to bolt the module directly onto an extruded, finned heatsink (see Maplin catalogue) with a surface area of at least 200cm^2.

The points to consider are:

1. Ensure plenty of space around the module for ventilation and air flow.
2. Bolt the bracket onto heatsinks or metal panels – not wood or plastic.
3. Flat panels themselves do not radiate heat readily and should have a finned heatsink attached.
4. Use a small mains or 12V fan as well, for extracting/blowing air over the MOSFETs when installed in confined spaces.

Setting Up

Fit low current fuses in each supply rail prior to powering up and do not connect a loudspeaker yet. Connect a multimeter, set to read current, in series with the +V supply rail – ensuring the current range selected is at least that of the fuse fitted – and turn on the supply. Assuming that all is well thus far, select a lower current range on the meter and adjust RV1 for a quiescent current reading of 100mA

DC. The actual value of 100mA is not critical on this amplifier and 80 – 120mA is fine. Turn off the power and after allowing a minute or so for the PSU electrolytics to discharge (CHECK!) remove the meter and reconnect the +V supply rail to the module. Re-connect the meter, set to read 50 volts DC or more, between the speaker output pin 1 and 0V. Power up again and there will probably be a small DC offset voltage of ±20 – 50mV here. If 0·5V or more is present then switch off and look for an assembly fault or check if one of the test fuses have blown. If any component appears to be getting hot or the quiescent current reading cannot be lowered then it is possible that the amplifier is oscillating. This effect usually manifests itself by R15 'cooking' due to the Zobel circuit absorbing generated RF energy. Re-check the PSU wiring and also capacitors C4 to C6 as they are easily broken during installation. Power down and install the 3A fuses for normal use.

In Use

Always take 0V connections from one place on a PSU – including the speaker 0V return. This is often referred to as 'star earthing' and ensures that eddy currents do not flow between different 0V points thus reducing hum and noise. The 0V point at which capacitors C101 and C102 join together, on Figure 9, is the best place to take connections from. When choosing a loudspeaker, ensure that it is capable of handling continuous power levels of 100 Watts RMS or more (8Ω version) and 150 – 200 Watts for 4Ω versions. Multi-banked speaker assemblies should not total less than 4Ω and must be connected together in parallel/serial combinations to achieve this. Remember that many speaker impedance figures are nominal and will vary according to frequency and applied power levels.

Over-driving the amplifier by applying input signals greater than 0·86V will cause the output waveform to 'clip' or square off. Square waveforms are rich in harmonics and can cause excessive excursions of a loudspeaker cone or more commonly, totally destroy a tweeter. Guitarists may like the sound produced, but speakers do not. When using any amplifier at high power levels, due consideration must be given to the application. Bass guitars and 'miked up' drum kits, for example, generate huge transients as strings are plucked or heads are struck. For these applications, devices such as compressors or limiters have to be introduced at the amplifier input – to protect speakers as well as the amplifier!

The MOSFET amplifier is robust and fairly 'bomb proof', but not invulnerable. If even greater power outputs are required then two amplifiers can be 'bridged' together in preference to driving one unit to its maximum. Finally, a word about earth loops. A correctly working MOSFET amplifier and PSU will not produce audible 50/100Hz hum by itself, but unscreened low level signal wires can introduce this. If the PSU 0V rail is connected to mains earth and other equipment connected to the mains earth have their inputs and outputs connected via screened wire to the amplifier, then a loop exists between the screen and earth wires. The mains supply generates an electromagnetic field that is very easily induced into the earth loop and hence the 0V rail will be carrying 50Hz signals, which are then amplified and heard at the loudspeaker. One method of reducing this common problem is to terminate the signal wire screen at one end of the wire only. The other end of the screen is then left unterminated. Another way is to connect mains earth to the amplifier case – containing amps and PSU's – but not to connect 0V to the case. On no account should any earth be removed from equipment connected to the mains – unless it has been designed for this purpose or double insulated.

MOSFET AMPLIFIER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1	2k2	1	(M2K2)
R2,3	47k	2	(M47K)
R4,5	3k9	2	(M3K9)
R6	1k	1	(M1K)
R7	33k	1	(M33K)
R8,10,11,13,14	100Ω	5	(M100R)
R9	12k 1W Carbon Film	1	(C12K)
R12	47Ω	1	(M47R)
R15	4Ω7 3W Wirewound	1	(W4R7)
RV1	1k Hor Encl. Preset	1	(UH00A)
CAPACITORS			
C1	10μF 35V Minelect	1	(JL05F)
C2	47pF Ceramic	1	(WX52G)
C3	47μF 50V SMPS	1	(JL47B)
C4	6n8F Polylayer	1	(WW27E)
C5,6	27pF Ceramic	2	(WX49D)
C7	100nF Polylayer	1	(WW41U)
C8,10	100nF Polyester	2	(BX76H)
C9,11	220μF 63V PC Electrolytic	2	(FF14Q)
SEMICONDUCTORS			
D1	1N4001	1	(QL73Q)
TR1,2	2SA872A	2	(UF75S)
TR3,4	2SD756	2	(QQ33L)
TR5	2SB716	1	(QQ31J)
TR6	2SK135	1	(QW10L)
TR7	2SJ50	1	(QW09K)

MISCELLANEOUS			
	Insulator TO3 [SIL]	2	(QY44X)
	Mosfet Amp PCB	1	(GA28F)
	Mosfet Amp Mtg.Bracket	1	(GA29G)
	Pin 2141	1pkt	(FL21X)
	Bolt 6BA x ½inch Long	1pkt	(BF06G)
	Nut 6BA	1pkt	(BF18U)
	Washer 6BA (shake proof)	1pkt	(BF26D)
L1	EC Wire 0·9mm *See Text*	1	(BL26D)
	Constructors' Guide	1	(XH79L)
	Instruction Leaflet	1	(XK39N)
OPTIONAL (Not in Kit)			
	Audio Toroidal 160VA	1	(YZ23A)
	J04	1	(BH46A)
	W01	1	(QL38R)
	4k7 1W Carbon Film	2	(C4K7)
	10,000μF 63V Can	2	(FF32K)
	2,200μF 63V Can	2	(FF22Y)
	100nF HV	2	(FA21X)
	100nF 35V Tantalum	2	(WW54J)
	μA78M12UC	1	(QL29G)
	μA79M12UC	1	(WQ89W)
	Fuse A/S 3·15A	3	(RA11M)
	Fuse A/S 630mA	2	(RA08J)
	Heatsink 6W-1	1	(FL77J)

The above items, excluding Optional, are available as a kit:
Order As LP56L (Mosfet Amp Kit) Price £19.95
The following items are also available separately:
Mosfet Amp PCB **Order As GA28F Price £2.45**
Mosfet Amp Mtg Bracket **Order As GA29G Price £1.16**

IR Remote Control System for NICAM continued from page 31.

IR TRANSMITTER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film			
R1	10R	1	(M10R)
R2	2R2	1	(M2R2)
R3	10k	1	(M10K)
R4,5,6,7	1R	4	(M1R)
CAPACITORS			
C1	100nF 16V Minidisc	1	(YR75S)
C2,3	100pF Ceramic	2	(WX56L)
C4,5	100µF 10V PC Elect	2	(FF10L)
SEMICONDUCTORS			
IR1,2	IR Emitter	2	(YH70M)
TR1	ZTX651	1	(UH47B)
TR2	ZTX751	1	(UH51F)
IC1	M708L	1	(UL67X)
MISCELLANEOUS			
CR1	455kHz Ceramic Resonator	1	(UL61R)
	Hand-Held Keyboard Case	1	(ZA00A)
	PC Board	1	(GE67X)
OPTIONAL			
	Alkaline AA Batteries	2	(FK64U)

IR RECEIVER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film			
R1,2,19,21	4k7	4	(M4K7)
R3,4,11,12	10k	4	(M10K)
R5,8	15k	2	(M15K)
R6,7	33k	2	(M33K)
R9,10,17	1k	3	(M1K)
R13,14	220R	2	(M220R)
R15	100R	1	(M100R)
R16	2k2	1	(M2K2)
R18,20,22	22k	3	(M22K)
RV1,2	1k Hor. Encl. Preset	2	(UH00A)
CAPACITORS			
C1	220µF 16V PC Elect	1	(FF13P)
C2,4,5,20	100nF Minidisc	4	(YR75S)
C3	10µF 16V Minelect	1	(YY34M)
C6,11,12,19	47µF 16V Minelect	4	(YY37S)
C7,8	4µ7F 35V Minelect	2	(YY33L)
C9,10	22pF Ceramic	2	(WX48C)
C13,14	1nF Ceramic	2	(WX68Y)
C15	2µ2F 63V Minelect	1	(YY32K)
C16	10nF Ceramic	1	(WX77J)
C17,18	470pF Ceramic	2	(WX64U)
SEMICONDUCTORS			
D1,2	1N4148	2	(QL80B)
TR1,2,3,4	BC548	4	(QB73Q)
IC1	LF351	1	(WQ30H)
IC2	LM13700N	1	(YH64U)
IC3	TBA2800	1	(JU36P)
MISCELLANEOUS			
	Instruction Leaflet	1	(XK36P)
	Constructors' Guide	1	(XH79L)
	PC Board	1	(GE68Y)
SK1	PCB Skt 12-Way	1	(YW30H)
PL1,2	PCB Latch PL 4-Way	2	(YW11M)
PL3	PCB Latch PL 2-Way	1	(RK65V)
	PCB Ltch Hsng 4-Way	2	(HB58N)
	PCB Ltch Hsng 2-Way	1	(HB59P)
	PCB Terminal	1 Pkt	(YW25C)
TP1,2,3	Pin 2145	1 Pkt	(FL24B)
	DIL Skt 8 Pin	1	(BL17T)
	DIL Skt 14 Pin	1	(BL18U)
	DIL Skt 16 Pin	1	(BL19V)
	Cable Twin	1 Metre	(XR21X)
OPTIONAL			
	IR Photodiode (see text)	1	(YH71N)

EXPERIMENTAL IR DETECTOR PARTS LIST

Please Note: The following items are *not* included in LP20W; and if required, they must be ordered separately. A kit is *not* available for these items.

RESISTORS: All 0·6W 1% Metal Film			
R1	4k7	1	(M4K7)
R2	3M3	1	(M3M3)
R3,4	47k	2	(M47K)
R5	150R	1	(M150R)
R6	10k	1	(M10K)
R7	680R	1	(M680R)
R8	100k	1	(M100K)
CAPACITORS			
C1,2	100nF Polylayer	2	(WW41U)
C3	1µF 63V Minelect	1	(YY31J)
C4	10µF 16V Minelect	1	(YY34M)
SEMICONDUCTORS			
IR1	IR Photodiode	1	(YH71N)
LD1	Mini LED Red	1	(WL32K)
TR1,3	BC549	2	(QQ15R)
TR2	BC559	1	(QQ18U)

The above items, excluding Optional, are available as a kit,
but are not shown in our 1991 catalogue:
Order As LP20W (NICAM IR TX/RX Kit) Price £29.95
The following items are also available separately,
but are not shown in our 1991 catalogue:
NICAM IR Transmitter PCB **Order As GE67X Price £6.25**
NICAM IR Receiver PCB **Order As GE68Y Price £2.95**
NICAM IR Transmitter Case **Order As ZA00A Price £5.95**
Other NICAM kits are as follows:
UHF TV Tuner Kit **Order As LP09K Price £39.95**
NICAM Decoder Kit **Order As LP02C Price £79.95**
Accessory Kit **Order As LP18U Price £69.95**
Complete NICAM Tuner System **Order As LP19V Price £139.95**
To power the completed NICAM tuner system it is recommended that you use the 12V regulated power supply type YZ21X Price £8.95.

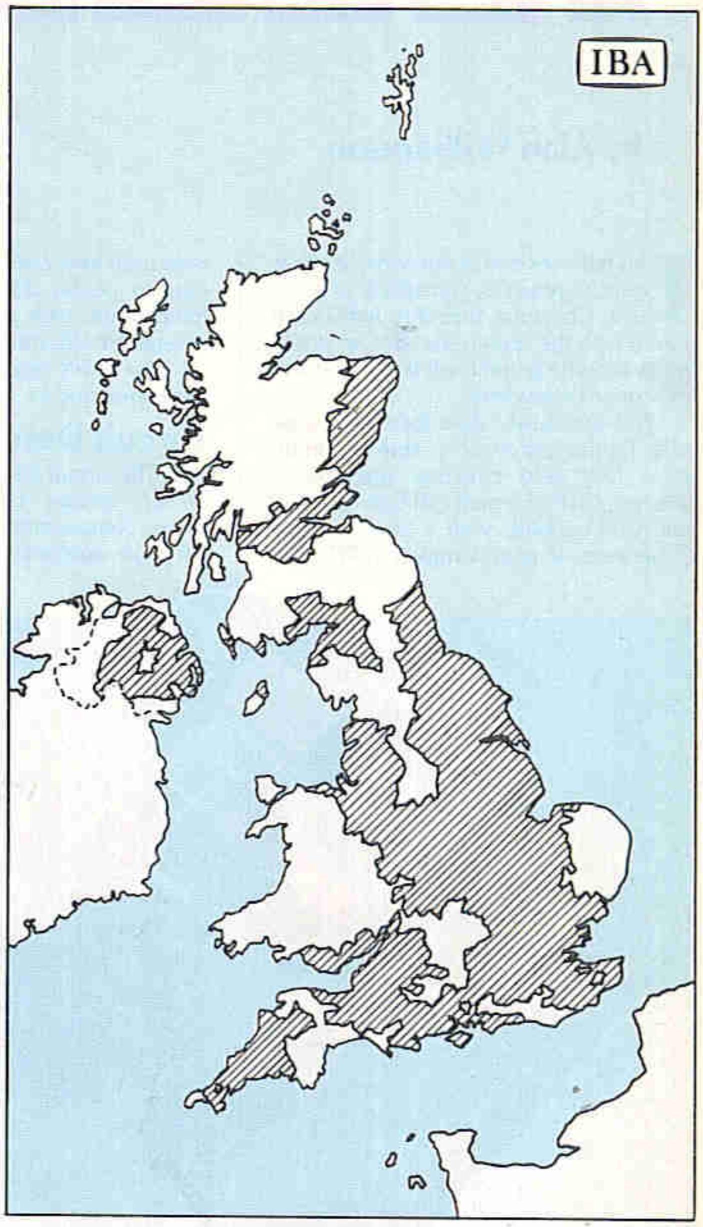
United Kingdom IBA NICAM Coverage

Transmitter and Relay Upgrade

By the end of 1990, a large proportion of the Independent Broadcasting Authority's television transmitter and relay network will have been upgraded. This will enable over 75% of the U.K. population to receive the NICAM-728 Digital Stereo TV Sound service on ITV and Channel 4/S4C programmes. The IBA NICAM coverage is indicated by the shaded areas on the map shown right. The following transmitters and their dependant relay stations will be providing NICAM coverage on the service dates shown:

Station	Programme Company	Service Date
Crystal Palace	Thames/LWT	Operational
Emley Moor	Yorkshire	Operational
Wenvoe	HTV Wales	Operational
Mendip	HTV West	Operational
Winter Hill	Granada	Operational
Black Hill	Scottish	Operational
Durris	Grampian	Operational
Caradon Hill	TSW	Operational
Sandy Heath	Anglia	Operational
Rowridge	TVS	Operational
Divis	Ulster	Operational
Caldbeck*	Border	Operational
Belmont	YTV	Operational
Dover	TVS	Operational
Pontop Pike	Tyne Tees	Operational
Sutton Coldfield	Central	November 1990
Bilsdale	Tyne Tees	December 1990

*Please Note: The following relays, served by the Caldbeck Transmitter, will not be providing the NICAM service: Kendal, Coniston, Hawkshead, Windermere, Grasmere, Crosthwaite, Sedbergh and Millthrop.



Are You Suitably Equipped?

If your television receiver or video recorder is not suitably equipped with a NICAM decoder then why not build the Maplin NICAM Television Tuner Unit LP19V Price £139.95. This stand alone unit can be added to your existing audio/visual setup, has the option for infra-red remote control (see page 24) and provides a whole host of facilities for the user. See Issues 23, 34, 35, 36, 38, 39 and 41 of 'Electronics – The Maplin Magazine' for full constructional details of the entire range of NICAM kits and details of how NICAM is transmitted and received.

NICAM

DIGITAL STEREO

IT'S WHAT YOUR EARS ARE MADE FOR!

zero CROSSING opto switch

by Alan Williamson

This is the second of our two Christmas novelty projects, something to make your Christmas tree fairy lights flash in time with the festive star, but no doubt this useful little project will find numerous applications elsewhere.

The previously described LED controller for the festive star is able to control up to four zero crossing, optoisolator switches, each of which can handle a 250 watt resistive load, with a triac package temperature of approximately 65°C. The triac used here *does not* have an insulated tab, so please *do not* try to verify the temperature with your finger as you will receive a nasty shock!

For safety reasons this project is not recommended for beginners.

Circuit Description

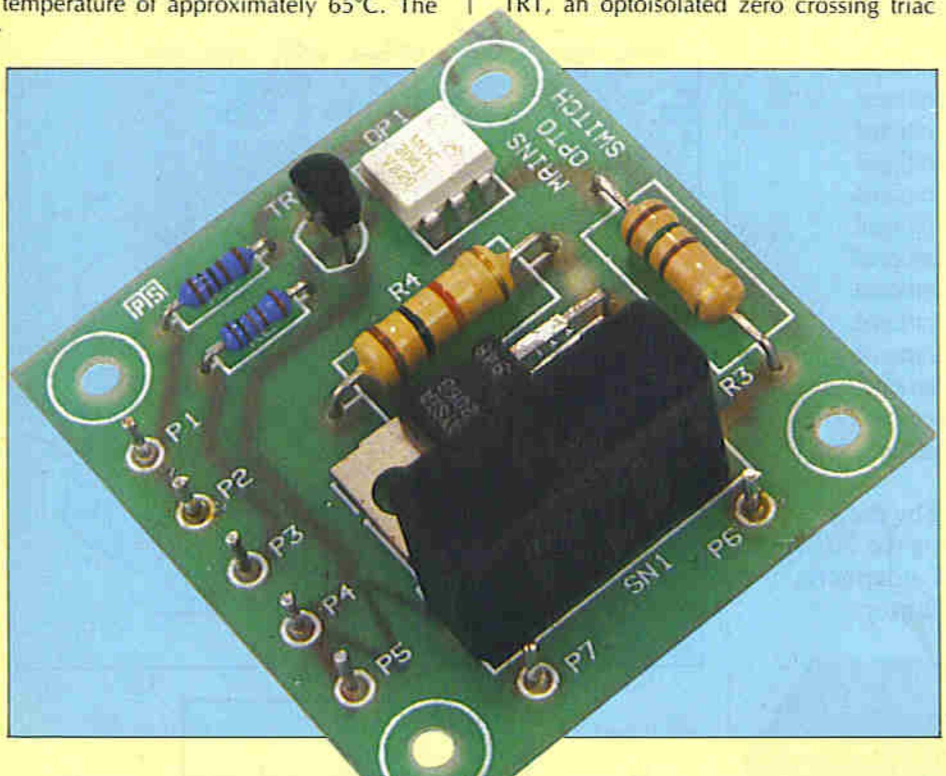
The circuit diagram shown in Figure 1 is very simple, consisting of just three major components. These are a transistor TR1, an optoisolated zero crossing triac OP1, and a power triac TI1. A zero crossing optoisolator was chosen to avoid the inherent interference problems associated with switching a load on while part way through the mains voltage cycle.

Transistor TR1 is used as a switch. Applying a positive voltage to P3 will cause a current to flow (limited by R2) into the base of the transistor (TR1); this current turns the transistor on, allowing a larger current to flow through R1 and the opto LED. The internal triac of the optoisolator will then fire the next time the mains supply crosses zero volts. Current is then fed via R3 to the gate of TI1, activating the power triac. Resistor R4 ensures that the power triac turns off whilst crossing the 0V part of the sinewave, and the snubber network SN1 suppresses any unwanted noise generated by the switching action of the triac (TI1).

Construction

As mentioned before this is a simple project, but for safety reasons it is *not* recommended for beginners; not only does the mains supply bite – IT CAN KILL! If you have no practical building experience and you would like to build this project, then please study the Constructors' Guide supplied with this kit very carefully.

Referring to Figure 2 and the Parts List, begin construction with the resistors first. The pins are inserted from the track side of the PCB using a hot soldering iron. After the PCB is completed, it should then be cleaned using alcohol, Ultraclene or PCB cleaner (Maplin stock codes YT66W and YJ45Y respectively).



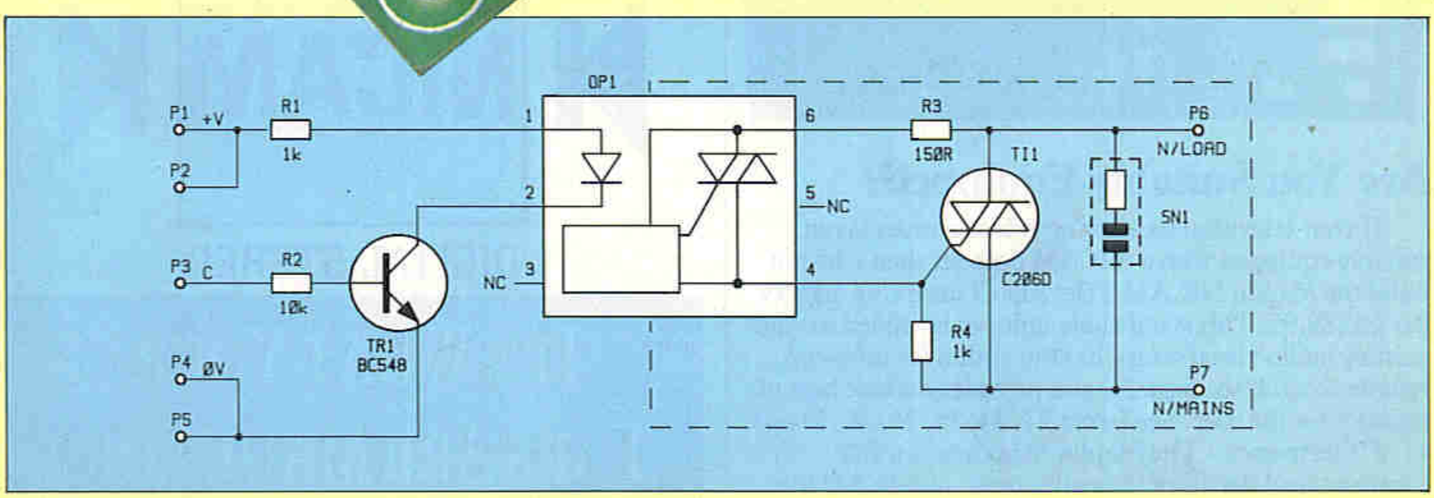


Figure 1. Circuit diagram.

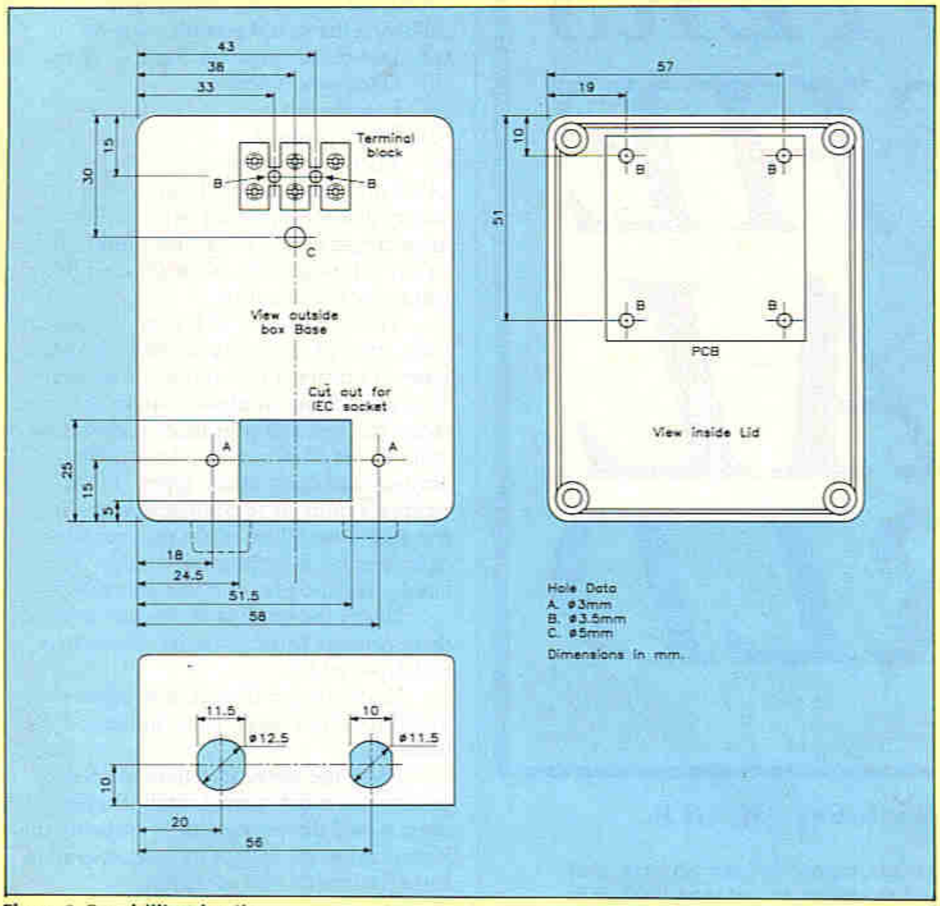


Figure 3. Box drilling details.

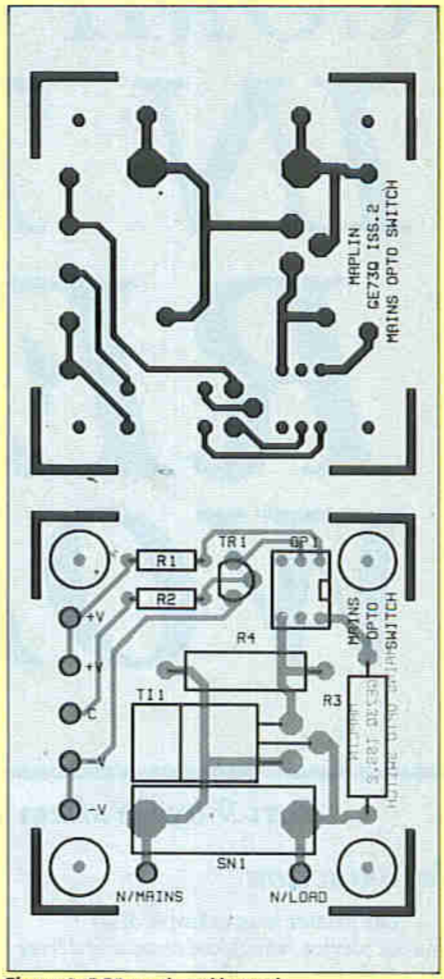


Figure 2. PCB track and legend.

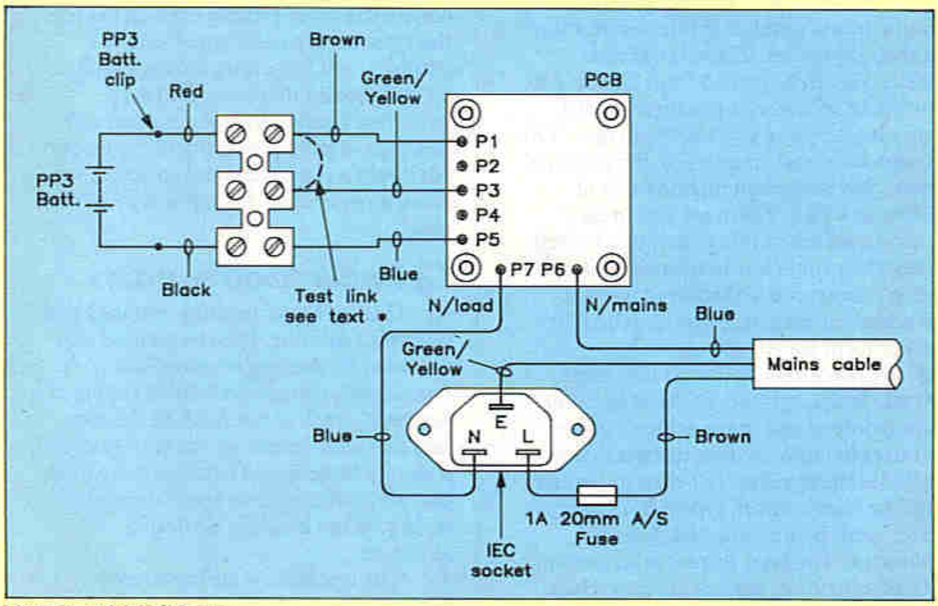


Figure 4. Wiring diagram.

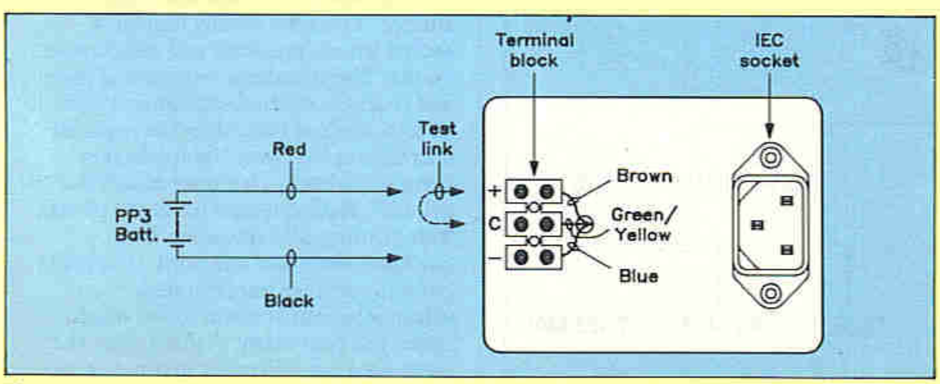


Figure 5. Box assembly.

Testing

Before testing can begin, the opto-switch must be safely housed in a non-conductive box; this will prevent possible injury to the user during testing and use. See Figure 3 for drilling details. The wiring of the optoswitch is shown in Figure 4, please follow the instructions carefully.

Having now fitted the project into a suitable box and completed the wiring, testing can now begin. You will need some kind of load, so dig out your fairy lights. Plug the lights into a 13A wall socket to check that they are working properly. Unplug the lights from the wall socket and change the plug if you wish to use the ELC type mains connector, and then plug the lights into the optoswitch's mains socket. Next, connect a 9V DC supply to the terminal block as shown in Figure 5, connect the optoswitch mains lead to a 13A wall socket and switch on. The lights should be off. To turn the lights on, connect a wire link from the battery positive to the control input (pin 3). The unit has now been tested and is ready for use. Figure 6 shows the interconnecting wiring between the two modules.

An alternative use for the optoswitch would be to use it as an interface for computers to control mains equipment, although the value of R1 would have to be reduced to 470Ω.

Continued on page 63.

COMPUTERS IN THE REAL WORLD

Part 9 by Graham Dixey C.Eng., M.I.E.E.

Introduction

The printer is an example of an 'output' device, which the computer drives to provide the user with 'hard copy' from his program. A familiar application of this type is wordprocessing. There is little point in writing and manipulating text on screen if a permanent copy of this cannot afterwards be obtained. Wordprocessing uses may include anything from a short letter, to a block-busting novel. Other software packages that require a printer at the final stage include spreadsheets (for accounting), databases (for record keeping), desk-top publishing or DTP for short (creating a mix of text and graphics for handbills, newsletters, magazines or books for example) and various drawing programs for generating original artwork.

To some extent the printer that one buys needs to be matched to the required end product. However, cost influences the choice as well. The price range is wide. It is possible to buy a printer for a little over £100 (the 'show bargain' price for some dot matrix models), but more sophisticated models, especially laser printers, may nudge or even exceed the £1000 mark.

This final article in the series will take a look at the various types of printer available and perhaps lift the lid on a few of their mysteries. There is a certain satisfaction to be gained from listening to the 'buzz' of a working printer, whilst one's masterpiece gradually emerges. This is especially true when using the graphics mode, but also when printing text of different styles. There are also great frustrations when things don't go so well; when the printer sits in obstinate silence, when it insists on underlining when it shouldn't or puts in totally uncalled for line or form feeds!

Printers may be placed into three broad classes, termed 'character printers', 'line printers' and 'page printers'. Most printers fall into the first category; this includes the familiar 'dot-matrix' printers and the 'daisy-wheel' types. Both of the latter work by printing character by character. The laser printer is an example of a page printer, since it prints a whole page at a time.

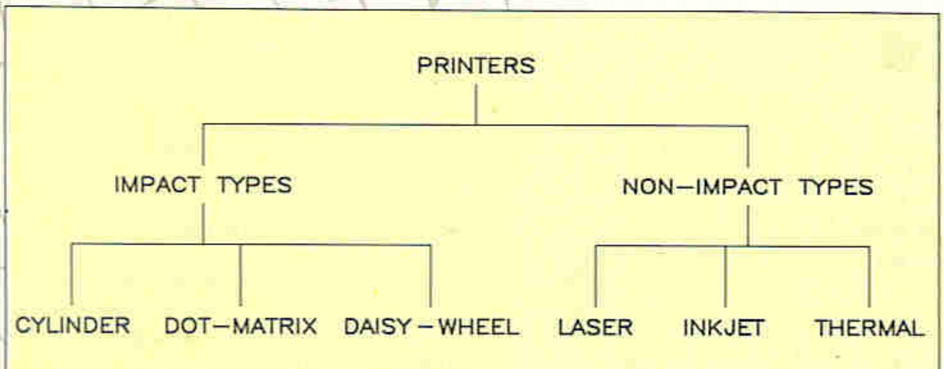


Figure 1. Family tree of available printer types.

If one were to conduct a simple survey of printer types, by reading the advertisement pages of computer magazines, supplemented by a dip into the occasional text book, something like the following list would probably emerge:

(a) Dot-matrix printers, 9-pin or 24-pin.
(b) Daisy-wheel printers.
(c) Laser printers.
(d) Inkjet printers.
(e) Thermal printers.

One might also conclude from such a survey that most printers print in glorious monochrome only (black and white!), but colour printing is also possible, at a price if you really want quality.

The 'family tree' of Figure 1 shows some attempt to classify the most common types of printer. From this it can be seen that, apart from the classifications of character, line and page made earlier, two other broad classes exist. These cover 'impact' and non-impact' types. These terms are unlikely to confuse anyone. It remains to see which of the printers later described fall into these two classes. The family tree also provides this information.

Under the heading of 'impact' we find three printers listed; cylinder, dot-matrix and daisy-wheel.

Under the heading of 'non-impact' we find three other types; laser, inkjet and thermal.

From the above selection, the one printer that most current small computer users would like to be using is probably the laser printer, because of its quiet operation and excellent quality of output. Realistically, such users are almost certainly chugging along with a 9-pin dot-matrix type, putting up with the less than perfect type and rather ragged graphics, not forgetting the high pitched buzzing sound that some find very irritating. Certainly, at the present time this type of printer dominates the market. No doubt a changing price structure will cause a swing away from this type at some time.

Cylinder head printers

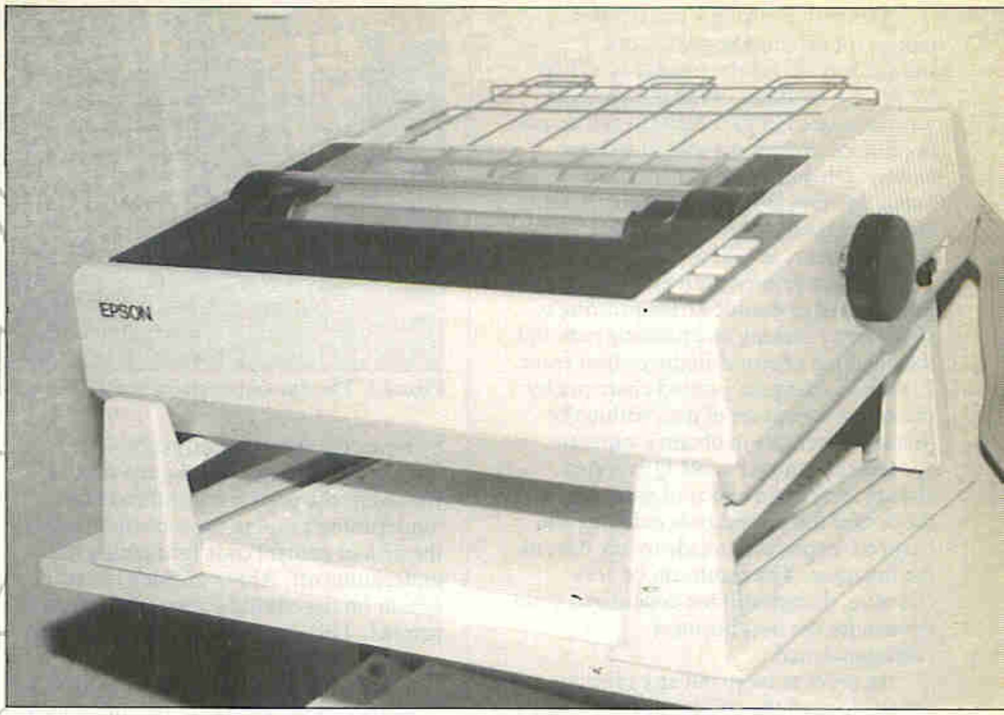
Our survey of printing methods will start with this one. It is the method that was used by the now obsolete 'tele-typewriter', commonly known simply as a 'teletype', such as the ASR-33. Having said that such machines are now outdated, it should be accepted that it is quite likely that a number of them are still going strong, in the hands of dedicated amateurs.

The mechanical arrangement is explained by Figure 2. The cylinder of the title has four rows of characters cast into its surface. These are usually limited to capital letters, numerals and punctuation marks. The cylinder is on a vertical pivot and is driven mechanically up and down to select a row and rotated for the required character in that row. Upon selection being completed, a hammer strikes the cylinder, forcing it onto the inked ribbon, thus printing onto the paper. Such machines were slow and noisy. The paper normally came in unperforated, continuous rolls of about $8\frac{1}{2}$in. width, rather less convenient perhaps, than the perforated fan-fold paper in common use today.

Now passing from yesterday's technology to todays, the next example that we shall consider is also the most common.

Dot-matrix printers

A matrix in this sense is a two-dimensional array of dots, capable of representing any of a very wide range of characters, alpha-numeric or graphical. The image is produced by striking the paper through an inked ribbon, much like that of a typewriter. But here the resemblance ends. Whilst the typewriter forms each character with a single stroke, the dot-matrix printer builds up the characters column by column as its print-head passes over the paper. This print-head incorporates a vertical bank of fine pins, which can be 'fired' electromagnetically at the ribbon. They then return under the control of a spring. In a 9-pin printer there are nine such pins. The matrix for a printer such as the Epson RX80 is nine (vertical) by five (horizontal) dots. To allow for underlining, only the upper area of 7 x 5 dots is used for the character itself. This leaves the 8th row available as a horizontal space, with the 9th row for the underline itself.



Example of a 9-pin dot matrix printer, the Epson MX80.

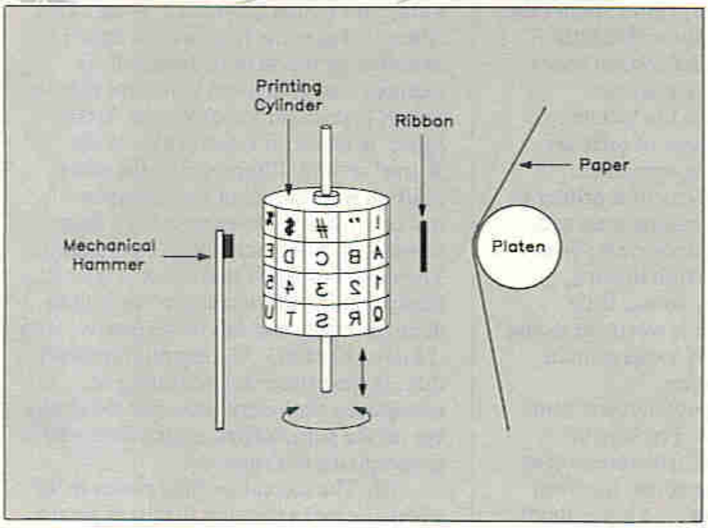


Figure 2. The printing mechanism of a cylinder head printer.

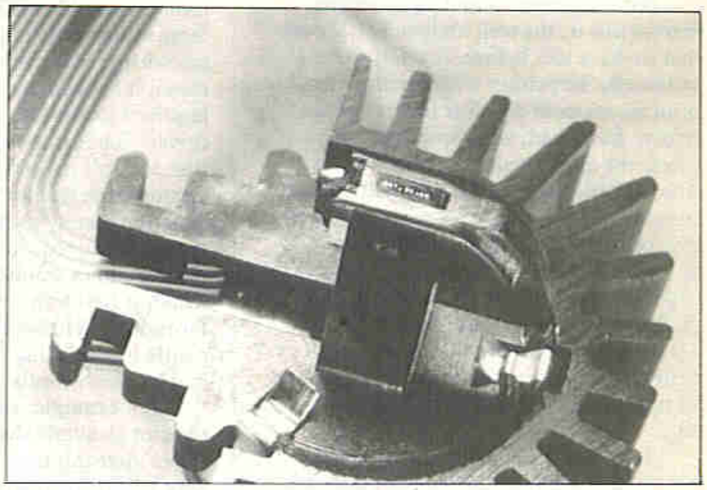


Photo 1b. The 'working end' of the Epson print-head. The nine pins are clearly visible, showing some signs of wear.

Photos 1a and 1b show the print-head in close-up. Photo 1a shows the underside of the print-head, a view not often seen; the pins referred to can be clearly seen. Photo 1b shows the 'working end' of the pins. It may be noticed that several years of regular use have resulted in the ends of some of the pins being somewhat hammered out.

The nature of the character printed depends upon which pins in the 9-pin column are fired at each instant. This probably needs little elaboration since most people regularly see the results of dot-matrix character formation, whether printed on paper or as text on a VDU screen. However, Figure 3 shows a typical dot-matrix character in the process of being formed. The character area of 35 pins allows a wide range of typefaces to be created. Examples found on most printers are: pica (normal), elite, italic, enlarged, condensed, double-strike, bold, superscript and subscript. An NLQ (Near Letter Quality) mode is also included nowadays. Some of these modes can be combined e.g. 'bold italic' or 'condensed enlarged', thus effectively giving further typefaces.

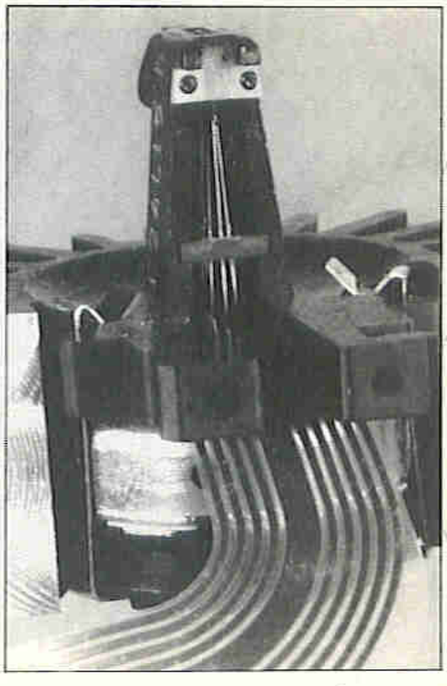


Photo 1a. Underside view of Epson 9-pin print-head showing the pins themselves.

While the 9-pin printer is popular and reasonably cheap, except in its NLQ mode the quality of output leaves a lot to be desired. Apart from using a totally different type of printer altogether, another possibility is to use a 24-pin dot-matrix printer. These are somewhat dearer, though there are some very reasonably priced models about now. The extra quality obtained by having a larger number of pins is quite dramatic.

It is possible to perform colour printing with this type of printer. A ribbon with three subtractive primary colours; cyan, magenta and yellow, is able to reproduce the three additive primary colours of red, green and blue by overprinting in the appropriate combinations. Often the ribbon is provided with black as well, for normal use. It has to be said that dot-matrix colour printers are quite basic in their capabilities and other technologies have to be employed for any great degree of sophistication.

Dot matrix printers use stepper motors for driving the print-head transversely across the platen, as well as for precise rotations of the platen. This was mentioned in Part Eight of this series, in connection with the uses of stepper motors. Obviously, control of stepper motor position has to be very precise in order that each of the columns that form each character, as well as the spaces between, are printed with exact regularity. Emphasised or double-strike printing is obtained by making one printing pass and then making a second slightly offset from it, so thickening the printed character by printing a second set of dots within the first set. Attempts to obtain a superior appearance, known as NLQ as stated already, rely upon a second pass also, with the dots of the second pass reducing the 'stepped' appearance made by the dots in the first pass. The result can be very effective, though still not considered good enough for the best business correspondence.

In order to carry out any printing operation at all the printer has to be sent a code sequence. A set of character codes defines each character: upper and lower case letters, numerals and punctuation marks; this is, the well known ASCII code that we have met before. A set of control codes tells the printer what typeface to print in, when to do a line feed, carriage return, form feed, what spacing to use, where the margins should be and so on. Any variable that you can think of when it comes to printing, is in some way covered by a printer code. When dealing with dot-matrix printers, the standard set of codes are those used by Epson. Most printers conform to these codes. After all, a code is nothing more than a number that defines an operation, so it makes sense that all printers should use the set (well nearly all!).

Looking through a printer manual reveals that many of the control codes are of the form ESC 'x', where 'x' is some alpha-numeric or other character defining the particular function. For example, ESC G turns on double-strike printing and ESC H turns it off again. So, if we want to print a short section of text in double-strike mode, we send the following code sequence to the printer:

27 71 "section of text to be printed" 27 72

The code 27 is ASCII for ESC; 71 and 72 are the ASCII codes for G and H, respectively. Seen in this light, printer control codes have no real mysteries after all! All that is necessary to do, is to insert the required printer control codes, at those points in the supply of data to the printer where certain actions are to be taken. Using a wordprocessor makes this easy; since all such codes are already built in, it is only necessary to make the appropriate keystrokes. For example, this article was written on an Amstrad PCW 8512 using Protext. With this particular wordprocessor, in order to underline a section of text, it is necessary to hit the ALT key followed by the X key (in order to gain access to the printer control codes), then type a 'u' (which appears in inverse video) immediately before the text to be underlined. The underlining is turned off by repeating the same sequence.

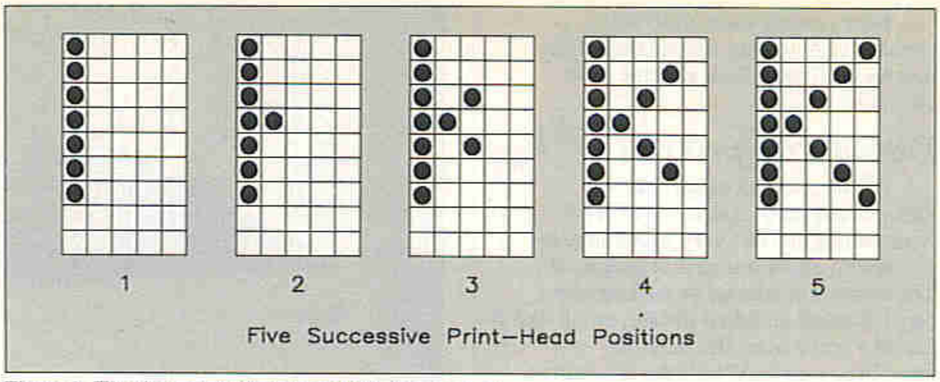


Figure 3. The dot-matrix character 'K' being formed.

In this example, typing the first 'u' will insert the printer control code for 'underlining'; typing the second 'u' inserts the printer control code for turning the underlining off. Although such codes appear on the editing screen, they are not printed. They merely control the printing action.

Although many printers are said to be 'Epson-compatible', there are sometimes minor differences. This is also true within the Epson range itself. Some of the codes used by the older MX80 printer are not the same as for the RX80. But with a little knowledge of what printer control codes mean, it becomes easy to make the required modifications to the 'printer driver'. The latter is a piece of software that controls the printing operation. Customising this for a particular printer or situation merely means calling it up and typing in the required parameters. With a printer comes an instruction manual, which at first sight, may seem a little formidable. However, it is worth spending a little time reading it; as it will contain much valuable information.

For example, suppose that you want to print on single sheets. The 'end of paper' detector may well frustrate you; as long before the full page of text has been printed, the printer stops and beeps loudly and at the same time the 'paper out' light flashes. Some wordprocessors will cope with this situation automatically when single sheet printing is selected. They will disable the above detector with software commands. However, not all do this. You are then alone with your printer manual! If you use it properly, you will find that there are two solutions to the dilemma; one uses hardware, the other software. Here they are for the Epson RX80:

(i) At the rear of the printer chassis are two DIP switches: switch 1 which is an 8-way and switch 2, which is 4-way. The tables that give the functions of these DIP switches are found in Appendix B. It requires only a moment to deduce that on switch 1, position 5 controls the 'end of paper' detector. It is factory set to the 'active' setting. Flipping it to the other position with the tip of a screwdriver makes it inactive, so preventing it from interfering with your single-sheet printing. The disadvantage is that, since it is a bit fiddly making this change, it tends to be done once only and left in the inactive state (I know, I did it!). All that this implies is that, in the future when printing on continuous stationery, it is wise to keep an eye on the paper supply, since there will be no safeguard if it runs out.

(ii) The second method comes to light when one looks through the list of printer

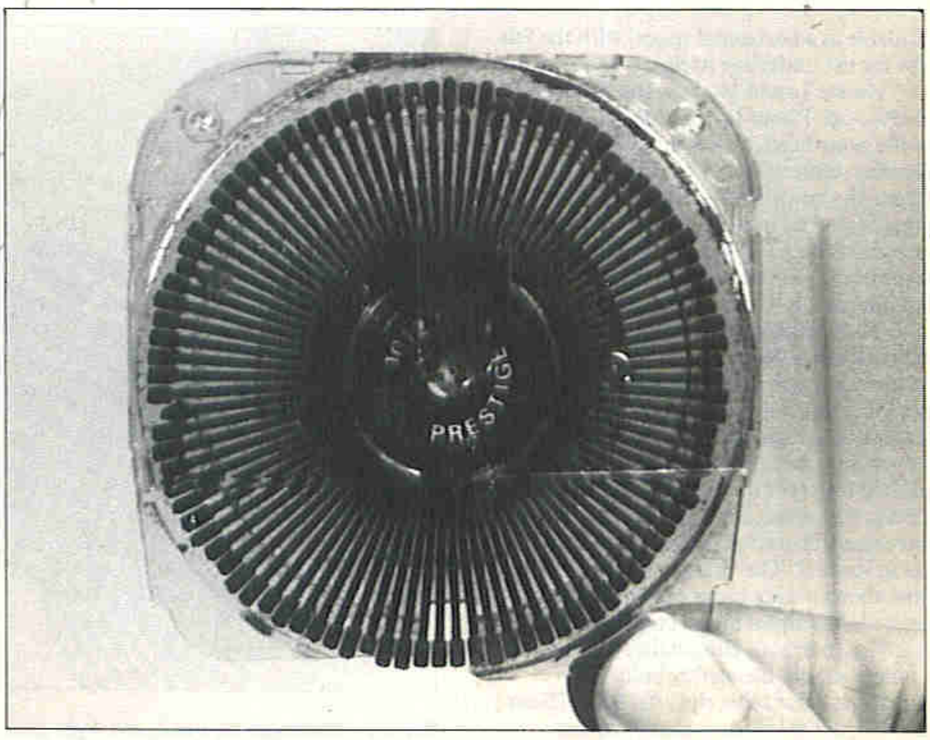


Photo 2. A typical 'daisy-wheel'.

control codes. It is found that ESC 8 will turn the paper end detector off, while ESC 9 turns it back on again. Thus, it is possible to include these printer control codes in one's program to permit single sheet printing when required.

This is merely one simple example of how familiarity with the printer manual can be of great help.

Daisy-wheel printers

While the dot-matrix printer is fast and versatile, what it lacks is ultimate quality. In the business world the latter consideration is often far more important than being able to draw pictures, print quickly or switch between various printing effects at will. One answer to this is the daisy-wheel printer, so called because of the plastic or metal wheel which carries the alpha-numeric characters at the tips of its 'petals'. Since each character needs its own spoke, there are likely to be 96 such petals in the wheel. Photo 2 shows a typical daisy-wheel has been included.

The daisy-wheel has an indexed reference position, from which it is spun round until the next character to be printed is aligned with an electromagnetic hammer. This hammer then strikes the tip of the spoke against an inked ribbon, giving an impression on the paper underneath. The direction in which the wheel rotates is always such as to give the shortest path to the required character. Since each character is fully pre-formed, by the very nature of the wheel, there is no compromise in the quality of the printed letter, numeral, etc. But there is also no way of changing from one type-face to another except by stopping the printer and changing the daisy-wheel. The exception to this is that underlining, double strike and other backspace effects can be called up. To use a daisy-wheel printer from a wordprocessor while retaining the facility of mixing the type styles means placing commands into the text that stop the printing operation at the required points and display a message on screen e.g. "change daisy-wheel now!"

Other drawbacks of the daisy-wheel printer are that they are incredibly noisy and extremely slow. Why they are slow is not hard to imagine. Whenever a new character is to be struck, the daisy-wheel has to be spun round to the correct angular position. Even when the shortest path is chosen, this takes valuable time. The complete print head assembly also has to be moved along to the next character position. The hammering of the wheel at a rate of, say, 20 characters per second is responsible for most of the noise, the level for which has been quoted at 75dB, about twice the acoustic power output of a dot-matrix printer.

One clever feature of daisy wheel printers driven by microprocessors is that the impact force can be related to the nature of the character printed. If, for example, the same force were to be used for printing a capital M and a full-stop, either the 'M' would be too light or the full-stop would perforate the paper. The way in which this is done is to convert a digital value representing the required force into a corresponding solenoid current to drive the hammer. A digital-to-analogue converter performs this function.

Provided that you can live with the minus points mentioned above, what these printers produce on the printed page looks very nice. For draft documents and run of the mill listings they are really not very appropriate. They are essentially for correspondence work only.

Laser printers

A simplified drawing of the physical arrangement of a laser appears in Figure 4. The design is based on an electrostatic drum or belt, which has a photo-sensitive coating. When coherent monochromatic light from a helium-neon or semiconductor laser strikes it at any point, that point of impact, as it were, becomes positively charged. This very small point becomes the smallest element of the image that is to be printed. The idea is similar to that of the 'pixel', which is the smallest element of the image produced on a television or computer display. By causing the laser beam to scan across the drum, line by line, as the drum is rotated, and turning the laser beam on and off, the electrostatic pattern of dots created forms the image of the page to be printed.

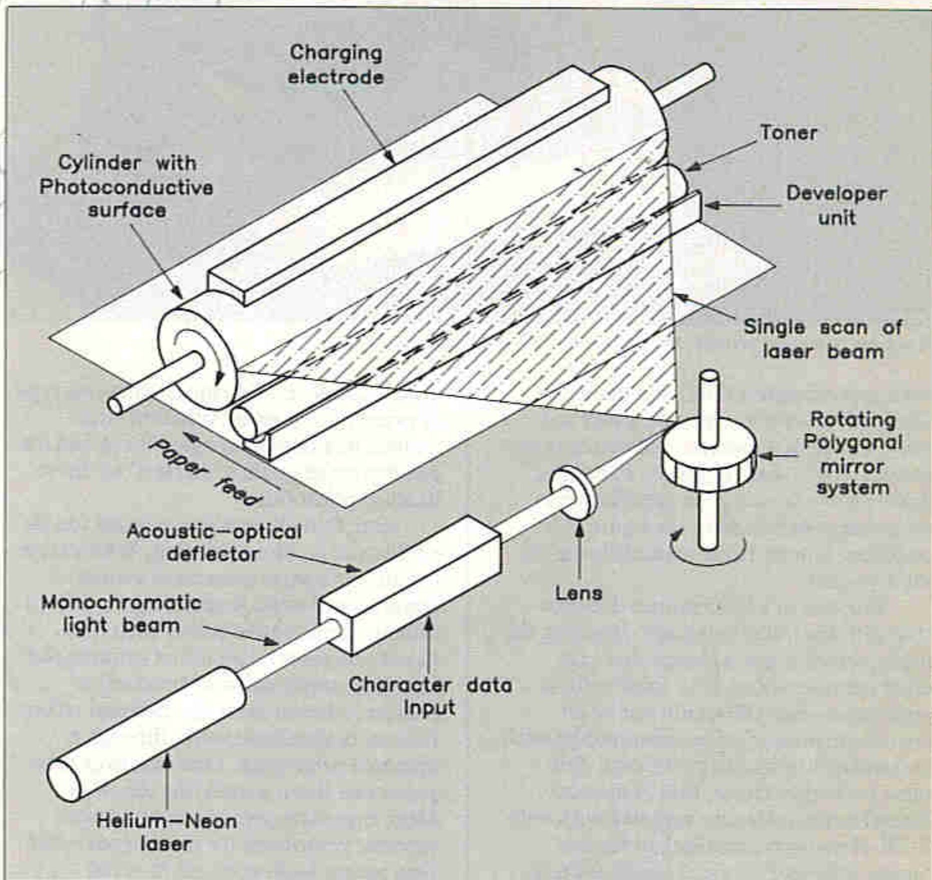


Figure 4. Physical arrangement of the laser printer.

Scanning is performed by using a lens to focus the laser beam on to a rotating polygonal mirror. As the beam hits one face of the mirror, the movement of the mirror causes a single scan of the drum. A regular scan pattern is formed because the drum and mirror rotate in synchronism. The dot-matrix characters are formed by switching the beam on and off under the control of an acoustic-optical deflector in the beam's path. This, in turn, acts according to the character data fed to it. A typical matrix is 18 x 24 dots; these are overlapped to improve the quality of the printed character.

Because a complete page (say of A4 size) is built up in this way, such printers are often known as 'page printers'.

To perform the printing process, the charged drum is next passed over a bath of toner (very fine black powder). The latter is attracted only to those areas on the drum which are positively charged. At this point the sheet of paper is fed into the printing path. This paper sheet has previously been given a very high electrostatic charge, far higher than the charge on the drum itself. As a result, the toner moves from the lower potential of the drum to the higher potential of the paper, thus forming a latent image on the paper. The image becomes permanent when the paper is fed though a pair of heated rollers.

It can be seen from this that the image formed by a laser printer is actually based on a dot pattern rather like that of a dot-matrix printer. The actual method is obviously quite different, giving the laser printer one of its primary characteristics – quietness of operation. However, the dot image of the laser printer is usually better than that of a dot-matrix type because of the greater number of 'dots per inch' (dpi). Nonetheless, there is little difference in quality between the top end of the dot-matrix market (24-pin printers) and the bottom end of the laser market. Both may have similar 'resolutions', 300 dpi being typical. This would put the dot size at about 0·085mm diameter.

The top end of the laser printer market, essential for desk-top publishing (DTP), with machines costing several thousand pounds, produces an image with a resolution four times better, that is 1200dpi. The corresponding dot size is

Example of a laser printer, the Panasonic KX-P4420.

then approximately 0·021mm diameter. The laser printer's work rate is fast and may be specified in terms of characters per second (cps) – 400 pcs for the Panasonic KX-P4420 – or it may be specified as so many pages per minute, the figure of 8 pages per minute being applicable for the same printer.

The cost of a laser printer does not stop with the initial purchase. Ignoring the paper, which is quite cheap, there are other considerations. The toner refill is quite expensive (£60 would not be an unrealistic price!); other consumables such as developer units add to the cost. But there is another factor, that of memory. Many laser printers are supplied with only 512K of memory, insufficient for any 'image intensive' work. A single A4 page of graphics requires 1Mbyte of memory! It is wise to make sure that memory can be upgraded and to check the cost of doing so. Other factors to consider are compatibility with the main 'page description languages' such as PostScript which interpret the commands given, to generate the dot patterns.

Laser printers come with a range of built-in fonts and yet more can be down-loaded. Software support is excellent and, when the prices drop rather more, many more people will doubtless be making use of them.

Inkjet printers

Inkjet printer technology is a form of dot-matrix printing, but the dots are formed by spraying liquid ink through tiny nozzles directly onto the paper. To produce high quality a large number of nozzles are needed, much the same argument as for the other types of dot-matrix printers. One major benefit that comes with inkjet printing is a very substantial drop in the noise level. There are no hammers, naturally! The ink is held in a reservoir from which it is drawn continuously during the printing process. At a price of £15 each, these reservoirs are quite expensive. This means that this type of printer is not really suited to large volume printing. Correspondence and the production of quality 'masters' are more likely applications.

One thing that inkjet printers can do pretty well is colour printing. Whereas, in colour dot-matrix printers of a more conventional type, several passes, using a different subtractive colour each time, have to be made, with inkjet printers the required combination of subtractive colours is drawn from the different colour reservoirs simultaneously, through a common print-head. One pass over the paper lays down a solid line of colour. More expensive colour printers have a separate print-head for each colour – but then we are looking at prices in the thousands of pounds range.

The system for an inkjet printer is shown in Figure 5. This shows that the term 'spraying' used above, while essentially correct, is actually a simplification. In a little more detail the operation is as follows.

The ink used is actually conductive and is forced through a very fine nozzle, producing a high speed inkjet. The nozzle is vibrated at some ultrasonic frequency, typically 100kHz, by means of a piezo-electric crystal and crystal driver. The effect of this action is to produce ink drops of constant size, about 0·06mm in diameter. The ink drops are each then given an electrical charge of specific value. The figure shows that this is produced in a charge electrode structure, which is controlled by the data to be printed.

The charged 'beam' of ink drops is then deflected in a deflection plate assembly, reminiscent of that in a cathode ray tube utilising electrostatic deflection. The horizontal plates may sometimes be omitted if the scan in this plane is by mechanical movement of the mechanism. The degree of deflection is determined by the individual charge on an ink drop. Those that are not charged at all, are collected in a gutter and returned to the ink reservoir.

For one specific case of an inkjet printer, it is stated that it takes 10^3 ink drops to form a single character. With ink drops being generated at the nozzle at the rate of 10^5 per second, this leads to a printing rate of 100 characters per second.

The inkjet printer is a close rival to the laser printer, though probably most people would opt for the latter. Its main advantage being quietness of operation. To approach the quality of laser printers there have to be at least 40 ink nozzles. With the few ink nozzles that some printers have, their performance is no better than many dot-matrix printers.

Notable inkjet printers come from Hewlett-Packard (HP Deskjet Plus) and Canon (Bubblejet). The former has 50 nozzles giving a resolution of 300dpi; printing speed is 1·5 pages per minute. The same resolution as for the cheaper laser printers but rather slower. Price is in the sub-£1000 region.

Thermal printers

Thermal printers were also mentioned in the list of available technologies at the beginning of this article. There are some incredibly expensive thermal colour printers, used like the laser printer for page printing. There is another type of thermal printer of the dot-matrix type that requires special paper. Alternatively it may use a thermal ribbon to print onto normal paper. This type of printer has little to offer in the face of competition from the other types of printer and it is doubtful if, as a means of obtaining hard copy from a computer, much real use is made of them nowadays. There is, therefore, little that need be said about them, apart from the above comments.

Printer interfaces

Printers handle their data in serial fashion. This is an obvious statement, since most of them are clearly seen to print each character in turn. Nonetheless, the way in which the data is passed to the printer may be through either a serial or parallel interface.

Essentially there are just two standard interfaces. The serial one is known as RS232C (or one of its derivatives) and the parallel one is known as the Centronics interface. The principles of both serial and parallel data transmission were discussed in reasonable detail in Part Five of this series.

Briefly then:

In the RS232C link the TTL levels are converted into two different levels, using negative logic, at the sending end and converted back again at the receiving end. Each character is sent as a separate 'data package' framed by start and stop bits. The serial mode uses only a single forward conductor plus a return, unless hardware handshaking (to indicate buffer full) is used and in this case additional conductors will be employed.

The Centronics interface uses eight data lines, plus handshaking lines, plus a large number of ground lines. A standard 36-way Amphenol connector is normally used. Cables connecting computer to printer are usually of necessity quite short, 1 – 1·5 metres being typical.

In using these interfaces, the characters are not actually sent one at a time as they are being printed. In practice, a 'stock' of data is held in a small area of RAM termed the 'printer buffer', which is replenished as required through link.

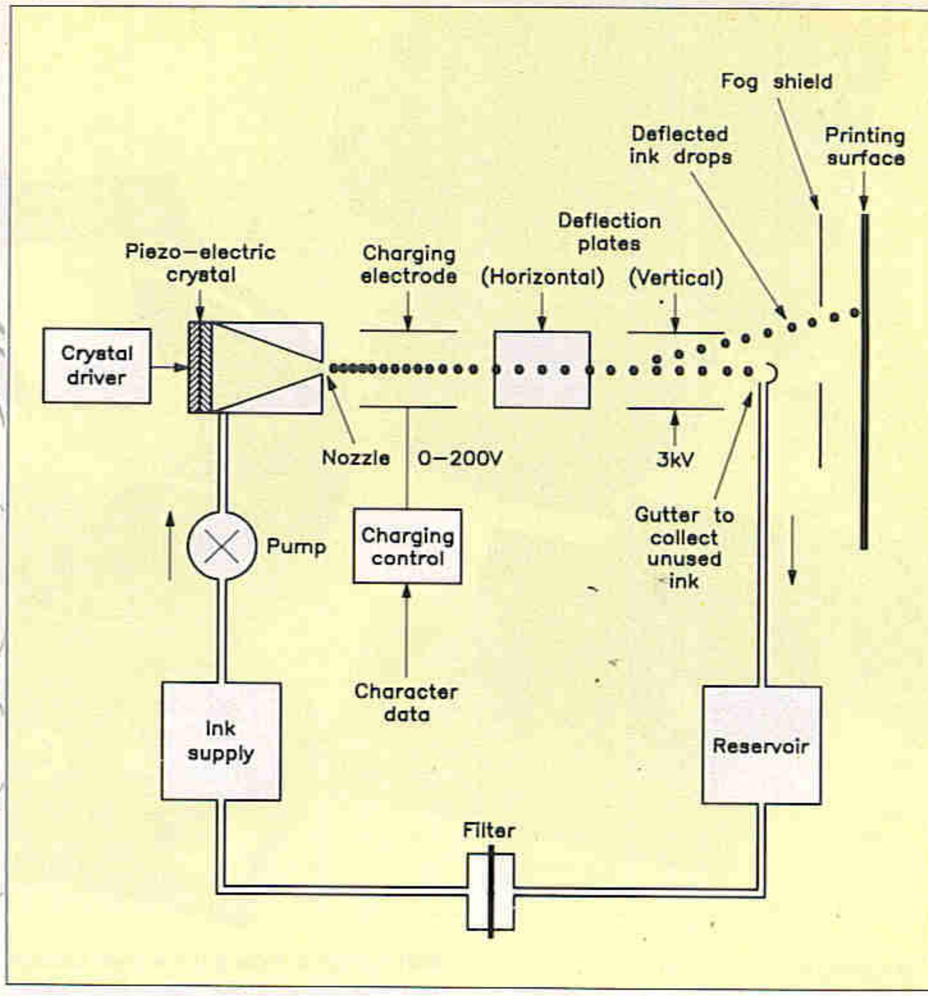


Figure 5. The inkjet printer.

Zero Crossing Opto Switch continued from page 57.

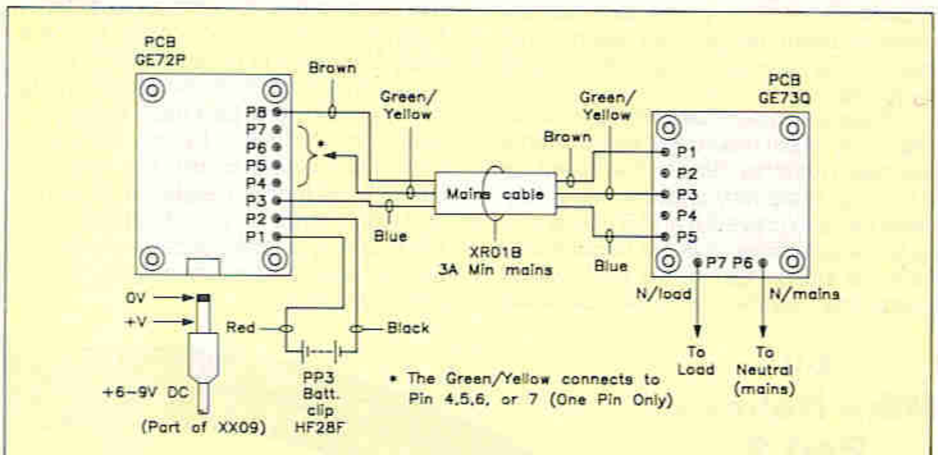


Figure 6. Interconnecting wiring.

Happy Flashing !

Specification

Maximum voltage, control supply:	12V DC
Maximum voltage, mains supply:	240V AC
Maximum power rating:	250W Resistive
Pin 1.	+V
Pin 2.	+V
Pin 3.	Control input
Pin 4.	−V
Pin 5.	−V

Pins 2 and 4 are used to link up other optoswitches

MAINS OPTO SWITCH PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (unless specified)			
R1	1k	1	(M1K)
R2	10k	1	(M10K)
R3	150Ω 1W Carbon	1	(C150R)
R4	1k 1W Carbon	1	(C1K)
CAPACITORS			
SN1	R-C Contact Suppressor	1	(YR90X)
SEMICONDUCTORS			
TR1	BC548	1	(QB73Q)
OP1	Zero Crossing Optotriac	1	(RA56L)
TI1	C206D Triac	1	(WQ24B)
MISCELLANEOUS			
P1-7	Pin 2145	1 Pkt	(FL24B)
	PC Board	1	(GE73Q)
	Constructors' Guide	1	(XH79L)
	Instruction Leaflet	1	(XK38R)

OPTIONAL (not in kit)		
ABS Box MB2	1	(LH21X)
Europlug	1	(HL15R)
Eurosocket	1	(HL16S)
Terminal Block 2A	1	(FE78K)
Safuseholder 20	1	(RX96E)
Fuse A/S 1A	1	(WR19V)
SR Grommet SR2	1	(LR48C)
Min Mains Black	3 Mtr	(XR01B)
Isobolt M3 20mm	1 Pkt	(JD17T)
Isonut M3	1 Pkt	(BF58N)
Isoshake M3	1 Pkt	(BF44X)
M3 Insulated Spacer 10	1	(FS36P)

The above items, excluding Optional, are available as a kit:
Order As LP55K (Mains Opto Switch Kit) Price £6.95
The following item is also available separately but is not shown in our 1991 catalogue:
Mains Opto Sw PCB **Order As GE73Q Price £3.25**

TAPED

by
Mike Holmes
Part 2

Resumé

In the last issue we discussed the fundamental principles of recording and electrical signal onto magnetic tape, and the sort of problems that can arise. In this second part the methods used by the electronic circuitry of a tape recorder to overcome some of these problems is dealt with.

Record Frequency Compensation

Recording amplifiers, as most amplifiers usually are, are of the constant voltage variety. Such an amplifier, delivering the record signal current to a record head, will not take into account the frequency dependent impedance of the head, and consequently the frequency response will be all over the place since the head will be very efficient at bass to midrange frequencies, and very inefficient at treble frequencies. Figure 6 provides an illustration of how record head impedance typically varies with frequency. Note that only the treble range appears to be affected, this is because at the lower end the impedance has reached 'rock bottom', i.e. the DC resistance value of the head windings.

What is needed is a constant current amplifier, where the *current* delivered to the head is constant for a given signal level required at any frequency, and the voltage across the winding is allowed to fluctuate as it will to maintain this current level. In practice this is achieved very easily by inserting a resistor in series with the record head, as R1 in Figure 7. The resistor usually has a high value, ideally at least ten times or more the impedance of the head at the highest frequency we wish to record. Now our constant voltage record output amplifier 'sees' the resistor as being the major part of the load, and any variations in record head impedance have negligible effect on the total impedance of the chain, and so the record current remains as nearly constant as is necessary for all practical purposes.

Figure 7 also illustrates the usual manner in which record and bias currents are mixed together. Bias is introduced via C1, which preferably should have a very small value to prevent it and R1 behaving as a low pass filter at audio frequencies! Its small value also goes a long way to preventing treble crosstalk between channels if a common bias source is used in a stereo machine.

The next problem is one of bias leakage back into the record amplifier, which if it possesses negative feedback will keep trying to compensate for it, adding distortion. Fortunately the relatively high value of R1 goes a long way to cutting this down to a minimum, and for some extra help a 'bias trap', comprising tuned circuit C2 and L1 can be added. With the values shown this resonant circuit adds further resistance at 50kHz, and which together with R1 also prevent the bias output being excessively loaded by the low output impedance of the record amplifier.

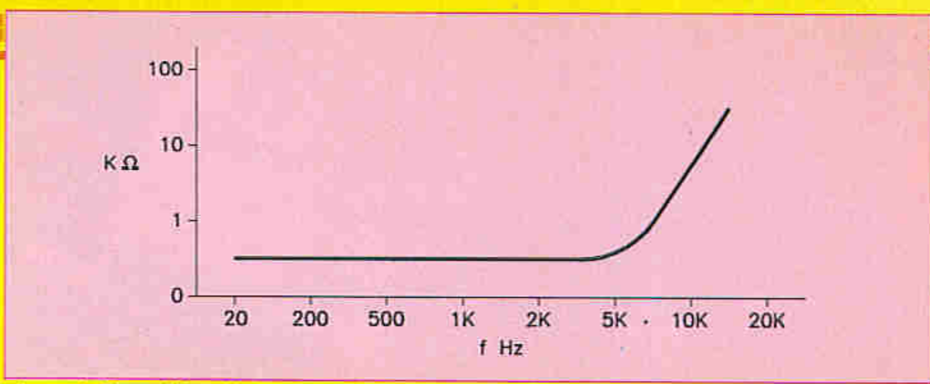


Figure 6. Record head impedance versus input frequency.

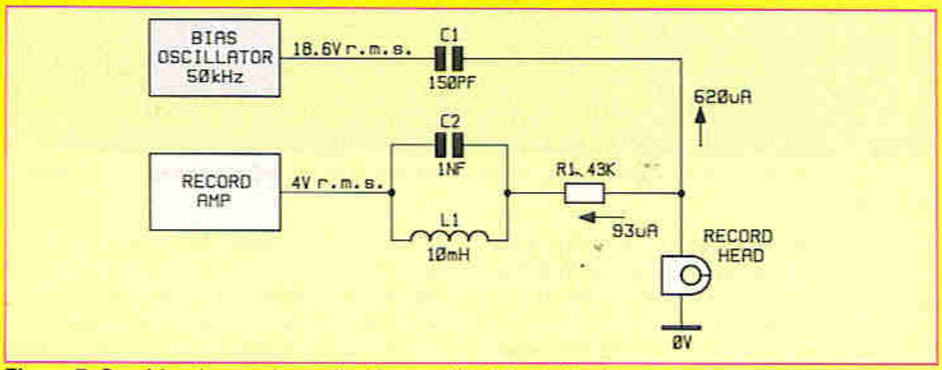


Figure 7. Combined record equalisation and AC bias 'mixer'.

The addition of R1 means that the amplifier's output needs to be quite high, considering the small value of record current actually required, and in the example of Figure 7 output needs to be 4V rms for a maximum record current of 92μA. The tuned circuit L1 and C2 has little effect at audio frequencies.

Record Level Metering

Some sort of record level indicator usually follows the record level potentiometer control in the chain of recording amplifiers. In recent years recorders are using bargraph LED displays more and more, driven by a bargraph driver IC. These do a very good job since only a small amount of effort is required to flash an LED, and so the meter has a fast response time. This is very important because the meter must indicate the peaks of the signal; if the music signal contained high amplitude peaks or pulses of short duration, these may go un-indicated and saturate the tape without us knowing about it. A half-wave rectified moving coil rms meter, as fitted to cheap recorders, is just not good enough. With tape recorders, it must be a *peak level meter*.

If the record level metering method does in fact employ a moving coil movement, then it can become a complex system in its own right if it is to indicate what is actually being put on the tape with any accuracy at all. It must have a full-wave rectifier, so it will respond equally to both positive and negative going half cycles of the signal, should have a fast response time, preferably measured in hundreds of microseconds, and then hold this level long enough for the meter movement to catch up with it and for us to see it, a time period of preferably a few seconds, before it decays to lower levels. This is usually achieved by having a power or high current amplifier dumping a charge, in proportion to the input level to the system, into a storage capacitor as fast as it can, and then this is allowed to leak away through the meter movement via a dropper resistor. Figure 8 gives an idea of what such an analogue peak level meter driver might look like.

Playback Frequency Compensation

Playing back the taped signal is not so straightforward either. To begin with, the magnetic energies on the tape are very tiny, and the playback head can from these produce a signal from its windings of only a very few hundred microvolts at most. Very small signal, high gain amplifiers are required, with the associated problems of instability, noise, pick-up, hum inducing earth loops, etc. For instance, take a high gain amplifier, connect an inductor (the playback head) across its input, add a little stray, phase shifted positive feedback, and what you invariably end up with is an oscillator. Ultrasonic, naturally. Consequently there isn't a tape recorder in existence that doesn't have a 'damping' capacitor wired across its playback head. The actual value is quite small, a few hundred pF is typical, but enough to 'kill' parasitic oscillation.

The next massive problem is the non-linear frequency response of the head during playback. Just how non-linear it is can be seen in Figure 9. This caused so much trouble in the early days that an official standard had to be set for playback frequency equalisation, if a recording played on several different machines was to sound the same! Several standards have been proposed over the decades from various authorities, but arguably the commonest in recent times is N.A.B. Like the R.I.A.A. equalisation standard for phonograph records, this magnetic tape playback equalisation standard known as N.A.B., after 'National Association of Broadcasters', stipulates what the frequency response curve of the playback amplifier should be, as in Figure 10a, which is as far as possible the exact opposite of that of the playback head, thus neatly straightening out the frequency response.

The non-linear playback response also makes it awkward to quote specifications for a playback head. Although a record head can be described by its DC impedance, dynamic impedance at 1kHz, mean bias and max. record current levels and pole gap width, how do you specify the output level of a playback head? The answer is that you fix a point of reference, which is recognised as 333Hz. As a guide then the output level of a playback head could be say 390μV

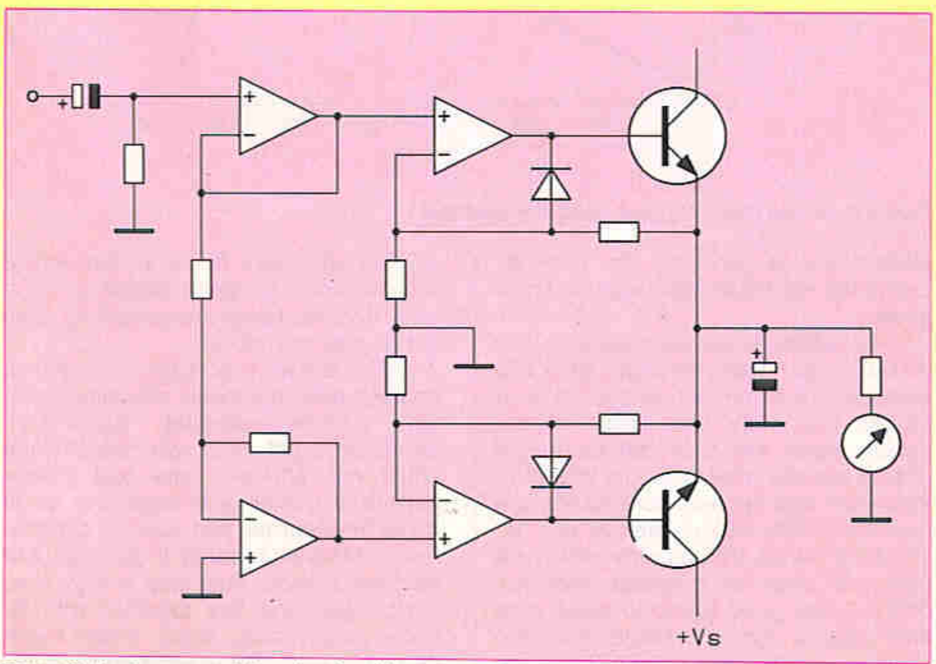
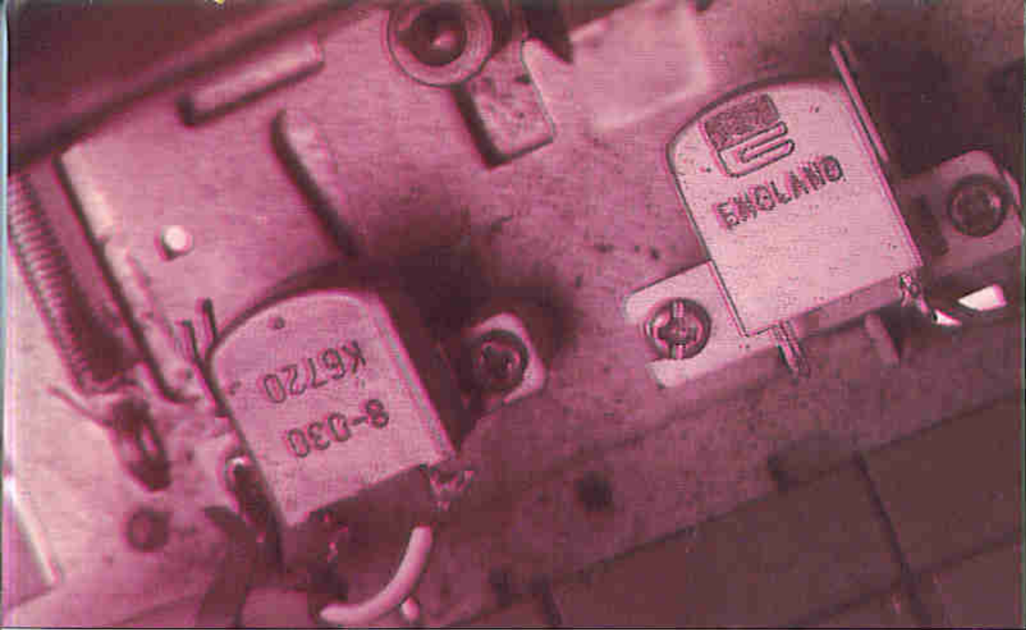


Figure 8. Analogue peak level meter driver.



Cassette head in close-up – erase head at left is upstream of record/play head near capstan pinch roller.

@ 333Hz, which gives us something to go on. What it actually means is that the output at 10Hz is miniscule, while at 5 – 7kHz it may exceed 1mV.

As it happens, equalisation may easily be implemented in practice by merely using a capacitor in the negative feedback loop to make gain dependent on frequency, since the reactive behaviour of a capacitor is exactly the opposite of that of an inductor. Simple. A playback pre-amplifier with N.A.B. equalisation is shown in Figure 10b, and this capacitor is C1.

Note how in Figure 9 the output of the playback head reaches a maximum at around 5kHz, then rolls off sharply to next to nothing in the space of 1½ octaves. According to the N.A.B. regulation, our playback amplifier must take this into account, and so a resistor, R3, is included (usually) to cause the 'downward trend' of the amplifier's frequency response to level off at a point equating with the playback head's maximum output. R3 simply prevents C1 reducing the amplifier's gain to unity at higher frequencies, and instead the gain is more or less flat from 5kHz on, as in Figure 10a.

Although the output still drops off above say 10kHz, this is how the off-tape signal is behaving and is not further attenuated by the amplifier. For a touch of sophistication, an inductor might be added in series with R3 and C1 to boost the top end (dotted line in Figure 10a), and try to flatten the play head's frequency response further, but in practice it isn't essential.

What *is* necessary is that the important levelling off point in the amplifier's response curve ties up with the peak output point of the tape head. Many reel to reel recorders are capable of running tape at two or three different speeds, which aren't arbitrary, but are well recognised as being 4.75, 9.5 and 18 cm/sec.: the latter offers superb frequency response at the expense of getting through tape rather quickly. The frequency response curve of the playback head is different for each of these speeds (although of similar shape), and requires that the relevant equalisation network, calculated for a given speed, also be switched into service when that speed is selected. The N.A.B. standard even allows for modification to the curve depending on pole gap width – 'high quality' heads have close tolerance, narrow pole gaps for best treble performance, while 'cheaper' heads have wider gaps and the treble roll-off occurs earlier.

Cassette versus Reel to Reel

Two decades ago the cassette, pioneered by Philips, won the favour of users world-wide over rival systems such as the cartridge. It is now an international standard, has made tape recorders and players very compact and very portable, and is easy to use for all and sundry. It should however be mentioned that the system makes problems for itself by cramming so much into such a small space.

Comparisons are necessary by way of illustration. Take the case of a two track mono reel to reel tape system as in Figure 11a. Here 'two track' means double sided, the tape can be turned over to use the other side. The tape is ¼ inch wide, and the recorder's heads use one half of this, hence sides 'A' and 'B'. The track is then 1/8 inch wide, which is a generous area of magnetic medium, offering very good signal to noise ratio and superior dynamic range. Also the signal strength is very good as there are many magnetised ferrous particles involved, resulting in a healthy playback level from the playback head.

Figure 11b shows this extended to four track stereo (two tracks per side). Note how the tracks are 'interleaved', or staggered, a curiosity of 'domestic' four track reel recorders. The disadvantage here is that each track, one for left and one for right, are halved in width to 1/16 inch. This immediately reduces the quality of the recordings as the tape area is halved, compared with the mono version. It is still, however, good enough. Dynamic range and frequency response are improved considerably by increasing tape speed, and a stereo reel to reel running at 18cm/sec. and possessing $3\mu m$ wide head gaps will easily accommodate the entire audio band with a flat frequency response from 20Hz to >20kHz. The absolute limit might be 30kHz if the bias frequency is 60kHz minimum (bias frequency must be at least double that of the highest frequency we wish to record).

Figure 11c shows how the cassette is even more compromised in this manner. The tape is reduced to a mere 1/8 of an inch, and if the player/recorder is mono then each track is 1/16in., which is not too bad, except that the tape speed is a measly 4.75cm/sec. As mentioned earlier the head pole gap has to be anything down to $1.5\mu m$ if a decent frequency response to just over 10kHz is possible, and which makes the record/play head ever so fussy about cleanliness! A stereo version has a pair of pole gaps sharing the same half of the tape, which is rather clever as this enables mono players to play stereo tapes. However, each track width is down to 1/32in., and there came a point where the demands for good signal to noise ratio, dynamic range and sensitivity could not be met any more.

The answer was to come up with an entirely new magnetic medium. Enter CrO^2 (chrome-dioxide) formulation, which provided what iron based tape could not. Chrome tape has greater sensitivity overall and especially so at treble frequencies, and superior dynamic range. More importantly it can take and hold much more magnetic energy than ferric tape, and this together with its treble performance, which allows treble de-emphasis or HF filtering on playback to improve S/N ratio, practically makes

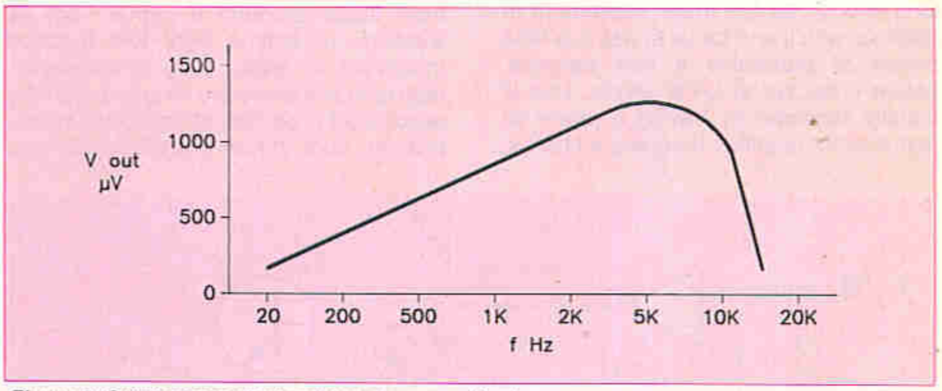


Figure 9. Output from playback head, unequalised.

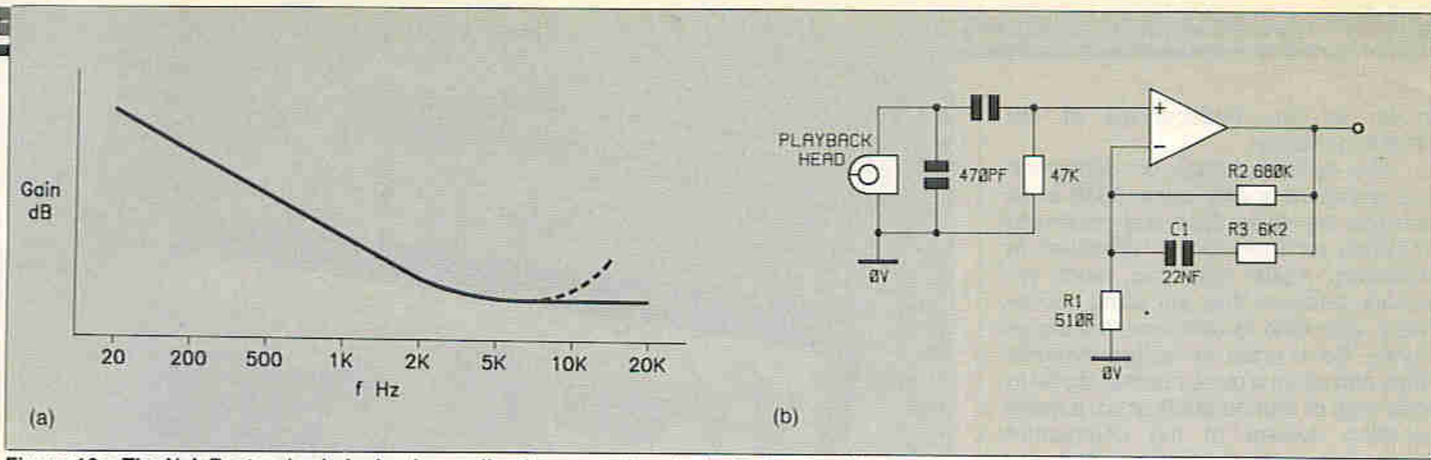


Figure 10a. The N.A.B. standard playback equalisation curve for playback pre-amplifier. Figure 10b. A practical N.A.B. equalised playback pre-amplifier. Open loop gain must be 60dB or greater.

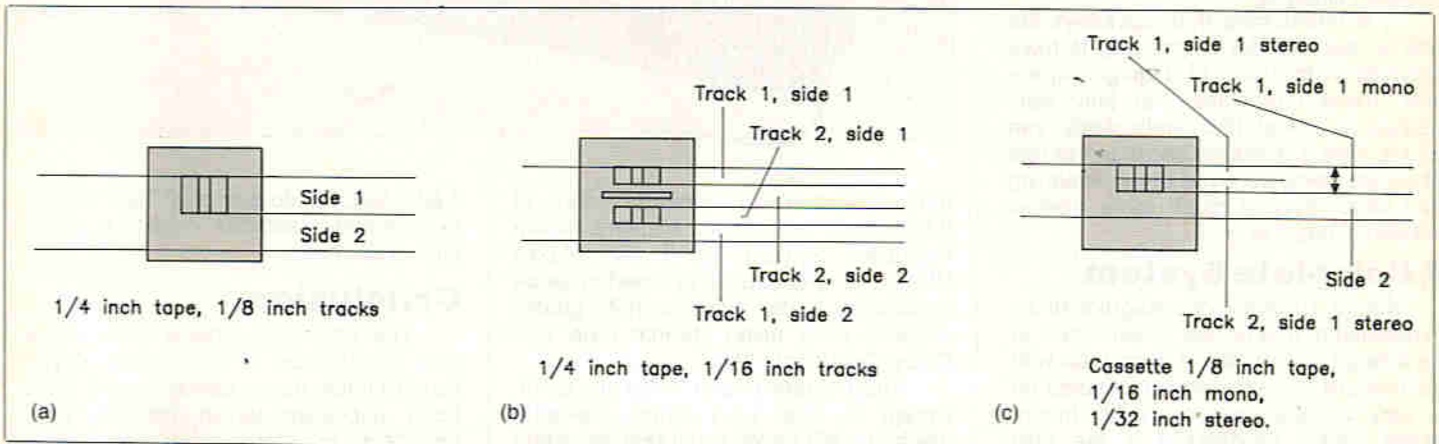


Figure 11. Organisation and dimensions of tracks. (a) Reel to reel mono, (b) stereo; (c) mono and stereo cassette.

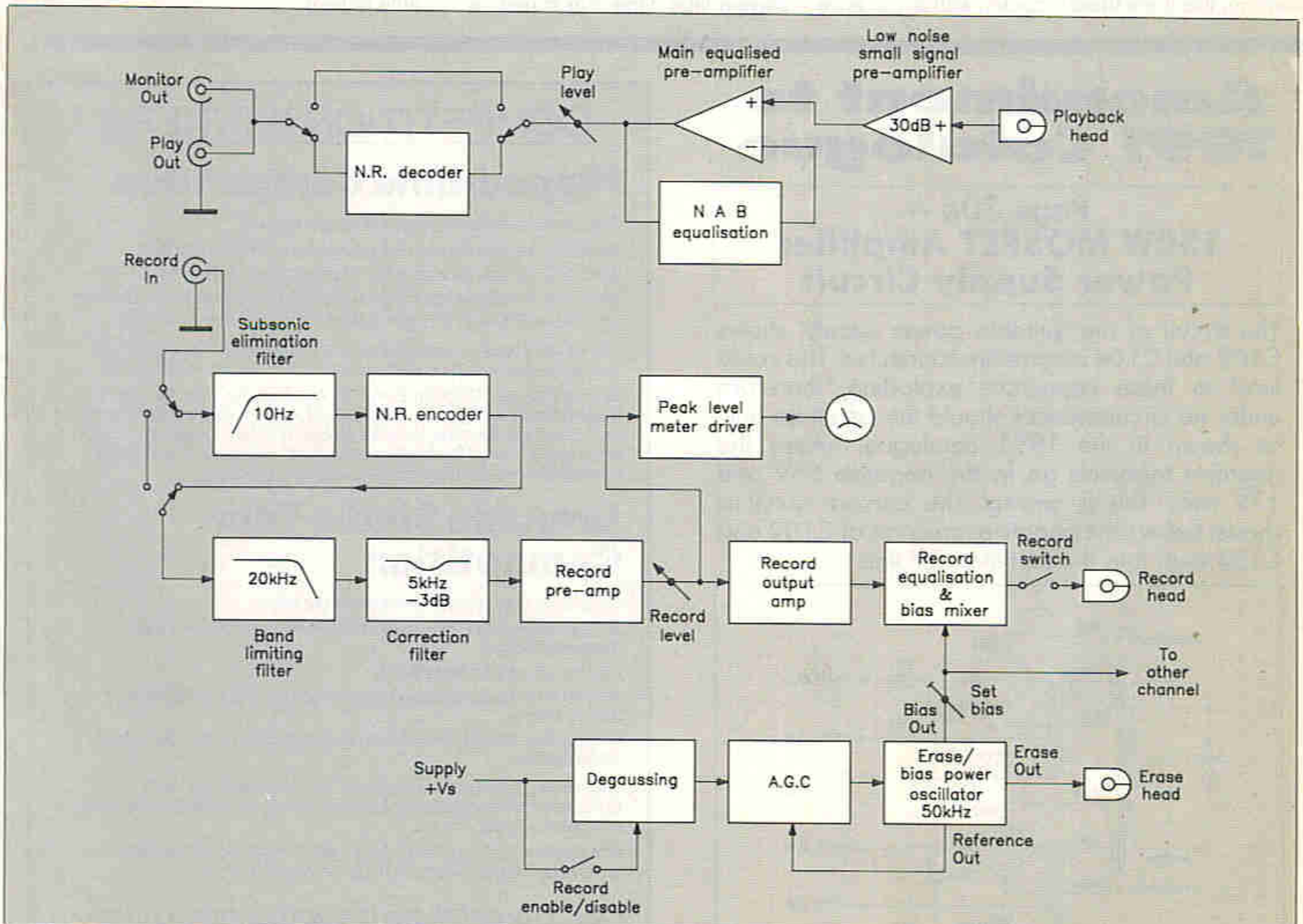
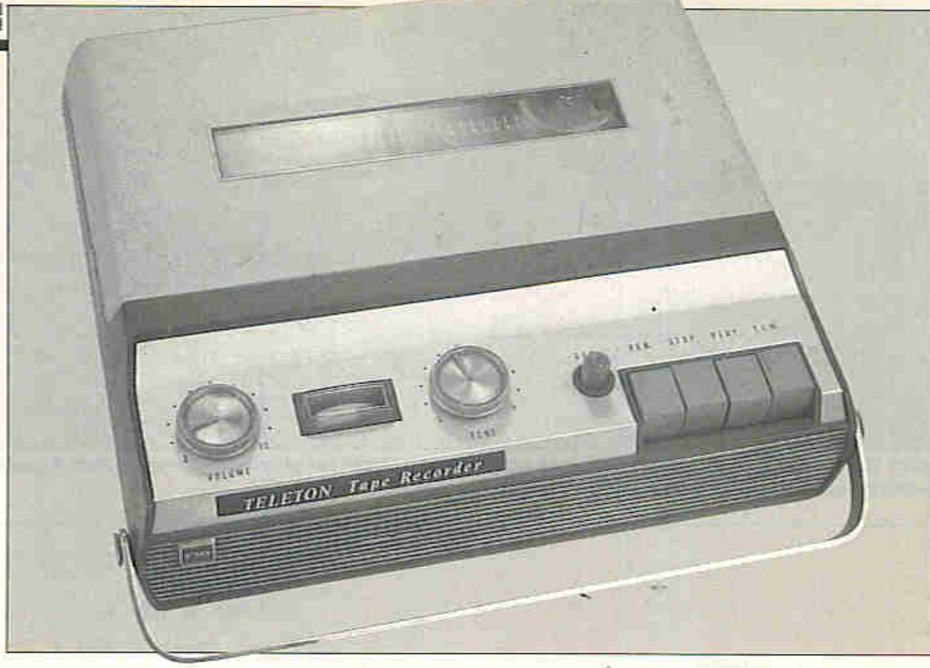


Figure 12. Block diagram of electronics for a workable high quality tape recorder (one channel of a stereo pair). 20kHz low pass filter in record chain prevents ultrasonic elements in the signal to be recorded producing audible difference signals when mixed with the 50kHz bias waveform, if present.

up for all the inadequacies of the cassette principle.

The dynamic range of 'consumer' tape recorders is 'only' some 40dB or so between the noise floor and maximum amplitude (or thereabouts, cassettes in particular). Aside from this, such recorders, because they are using narrow tracks, also tend to compress the signal slightly. So in order to restore dynamic range and attain a more realistic signal to noise ratio of around 80dB or so, a noise reduction system of the compander variety is currently in vogue, such as the consumer standard Dolby B, or the more exacting Dolby C.

It is unfortunate that nowadays the reel to reel recorder seems only to have survived in the form of a mega expensive, hyper-fi machine that only well-heeled, fanatical hi-fi enthusiasts can afford. This is a shame because the rest of us are being deprived of experiencing that which even a much more modest version is capable of.



A Complete System

Figure 12 is a block diagram of an experimental reel to reel system, built in an attempt to see how it compares with the modern cassette medium. Based on a very ancient tape transport mechanism, which incidentally is the only surviving original part from the donor machine, this three head recorder, with a tape speed fixed (unfortunately) at 9.5cm/sec., and using Maplin's Noise Reduction System Mk II with Maxell UD18-180 ferric tape, has a performance noticeably better than a hi-fi quality cassette deck using chrome tape with Dolby C, but only just.

There doesn't seem to be any point, except in one area where cassette machines will never equal reel recorders similar in every other facet of performance – playing time. One 7 inch reel, or 3,600 feet, of 'double play' tape on the experimental recorder equals a grand total of six hours.

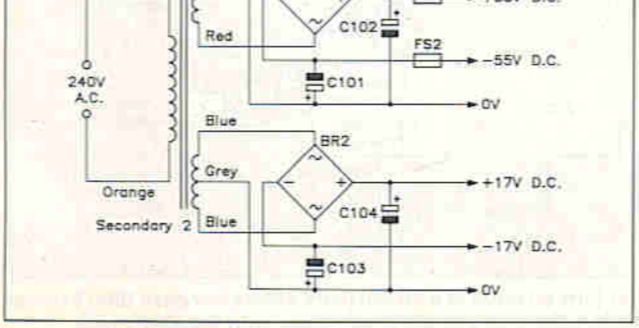
Conclusion

This concludes what is really only a brief introduction to the subject. If you want to know more, several books have been published which go into tape recorders in more detail, and your friendly neighbourhood library should be able to help.

Amendment to 1991 Catalogue

Page 306 –
150W MOSFET Amplifier Power Supply Circuit

The circuit of the 'suitable power supply' shows C102 and C104 incorrectly connected. This could lead to these capacitors exploding; therefore under no circumstances should the circuit be built as shown in the 1991 catalogue, where the negative terminals go to the negative 55V and 17V rails. This is wrong! The correct circuit is shown below, the negative terminals of C102 and C104 must join the common 0V line.



COMPETITION WINNERS

Hippodrome Competition

The questions and correct answers were as follows:

Name Michael Jackson's two top selling albums: **Thriller and Bad.**

Which U.S. city was featured in the TV series "Fame"?: **New York.**

Where was the original Hippodrome located?: **Cranbourn Street, London.**

Who starred in "Dirty Dancing"?: **Patrick Swayze and Jennifer Grey.**

The following lucky people who entered the Hippodrome Competition will receive Double Tickets for FREE admission to the London Hippodrome:

Mr Chris Plummer, Paignton, Devon; Mr A. J. Plummer, Paignton, Devon; Mr Eddy Plummer, Paignton, Devon; Mrs M. C. Plummer, Paignton, Devon; Mr C. Shepherd, Swindon, Wiltshire; Mr Cyril D. Blount, Dodworth, Barnsley; Mr Michael Cooke, Doncaster, South Yorkshire; Mr J. Shevelan, Hayes, Middlesex; Miss J. Shevelan, Austwick, Lancaster.

Granada Studio Tour Competition

The questions and correct answers were as follows:

In "Coronation Street" the brewery house owning the "Rover's Return" is: **Newton & Ridley.**

Spot the odd one out: **Mary Scott.**

Who wrote the Granada television drama series "First Among Equals"?: **Jeffrey Archer.**

Which of the following personalities have appeared in "Coronation Street"?: **Violet Carson.**

The following lucky people who entered the Granada Studio Tours Competition will receive Family Tickets (admits four) for FREE admission to the Granada Studio Tour:

Mr Keith Allen, Reading, Berks.; Mr A. Bell, Grimsby, South Humberside; M. Rowles, Caoxton, Neath; W. R. Collins, Malvern, Worcs.

Don't forget there is another great prize-winning competition on page 42.

1kW MOSFET Amplifier

Update

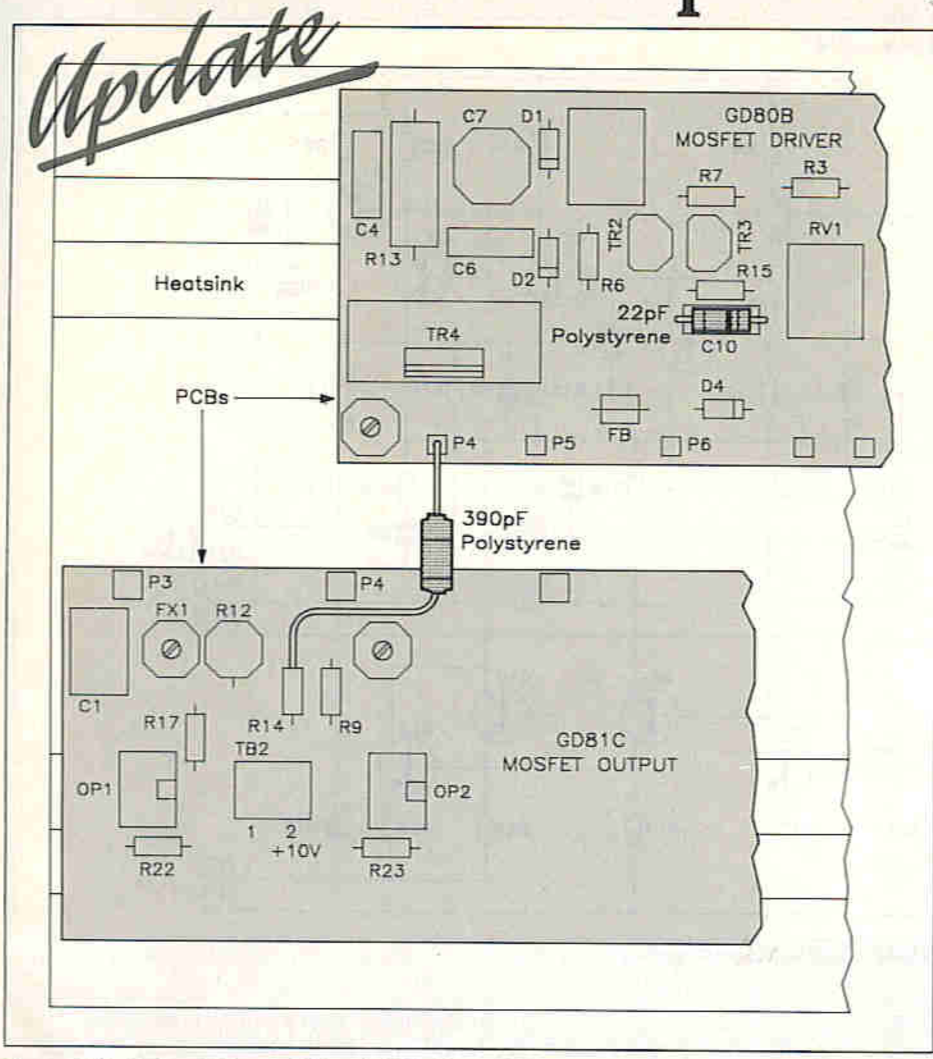
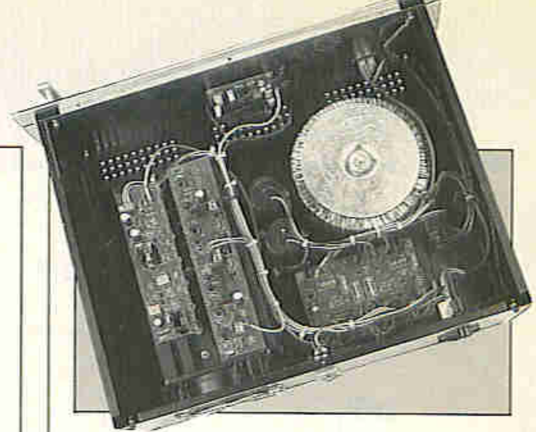


Figure 1. Replacing C10 and adding the 390pF capacitor.



Some customers have experienced problems with this amplifier due to instability. The problem can manifest itself in the form of mains hum, audible from a connected loudspeaker, which becomes more or less apparent depending on where the amplifier is situated. The expected noise output is usually very low and when viewed on an oscilloscope, wideband and hum noise levels in the order of 10 to 20mV would be seen to be present. With the input pins shorted (or open circuited) and the low frequency component audible, a few amplifiers have exhibited 2 to 3V of RF signal modulated by a 50 to 100Hz signal.

The amplifier has a very wide frequency response and high slew rate, which is desirable for good quality sound reproduction, but does render it susceptible to external RFI (radio frequency interference) – Cellular radio telephones are a typical example of this.

Also, due to the number of MOSFETs used in the design and the large differences in input capacitance between 'N' and 'P' type MOSFETs, some amplifiers have been noted to become unstable at medium output power levels – approximately 100 to 200W. The effect when viewed on an oscilloscope approximates small, low frequency square wave bursts, within the signal waveform, and can be more prevalent following every large signal excursion or clipped transient.

The Design Laboratory have pointed out that this is not the normal behaviour of the design, neither is it a common occurrence, but in the interest of maintaining the high standards expected of this project, a few simple modifications have been developed which will cure any such problems experienced as follows:

1. A pre-punched, galvanised steel, 19in. rack type case is available (XM13P) which is designed to house the amplifier. Various other installation hardware is also available as a kit (LM65V) supplied complete with the case. With the case grounded to mains earth, the amplifier's susceptibility to RFI is greatly reduced; the case is therefore highly recommended.

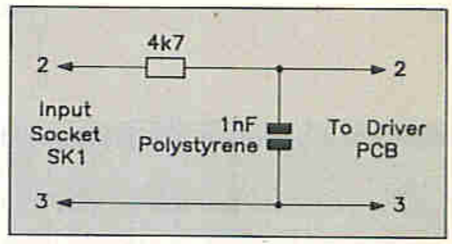


Figure 3. Circuit of RC filter.

2. On the Driver Module (GD80B) replace C10 (100pF polystyrene) with a 22pF polystyrene capacitor (BX24B) as shown in Figure 1.

3. Fit a 390pF 1% polystyrene capacitor (BX52G) between the Driver Module (GD80B) pin 4 and the junction of W/W resistor R12 and R14 on the Output Module (GD81C) as shown in Figure 1. The drawing assumes that both Driver and Output Modules have been installed onto the heatsink as shown in the project instructions supplied with the kit.

4. Fit a low pass RC filter between the input XLR socket, SK1, and the input pins of the Driver module as shown in Figure 2. The simplest way to install the filter is to solder the two components straight onto the back of SK1 with an 4k7 resistor (M4K7) soldered to pin 2 and 1000pF (1nF) capacitor (BX56L) to pin 3. Solder the two unterminated leads together and connect the core of the input screened cable to them. Connect the cable screen to pin 3 on SK1. The remaining end of the cable is fitted as per the original project instructions.

If these modifications are to be installed as a matter of course before assembling the modules, then on the Driver Module, R1 can be increased to 4k7 and C3 increased to 1nF instead of fitting these components on the rear of SK1.

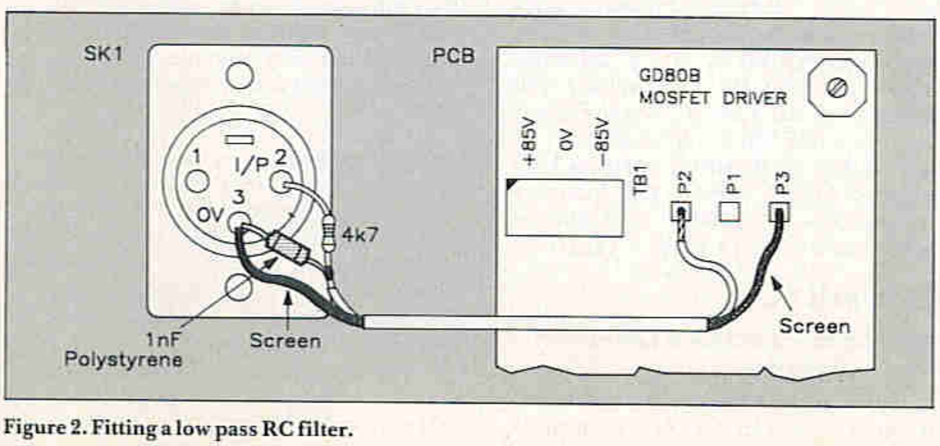


Figure 2. Fitting a low pass RC filter.

Audio-Frequencey Induction Loop Systems continued from page 47.

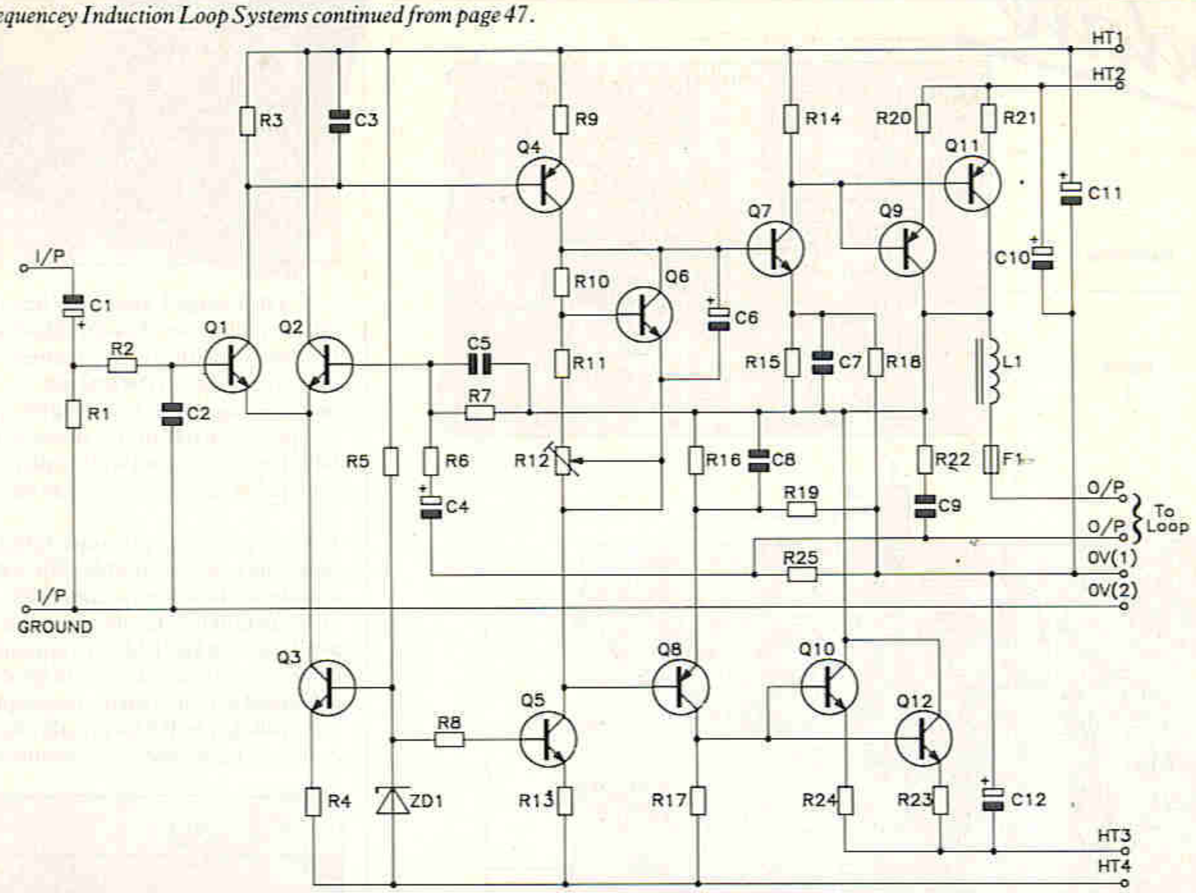


Figure 22. Experimental high-output amplifier with combined voltage and current feedback.

amplifier needs an equally high-quality preamplifier, with balanced-input microphone amplifiers, a mixer stage, long-term AGC *and* compression, bandwidth limitation etc., etc. This is all too much for the present series, but more may be heard of this project later. Keep taking 'the mag.'!

Next Time

In the next part, we shall look at some of the less obvious factors which need to be taken into account in designing, installing and *using* an AFILS, such as where you put the microphones, how you set up the system, and, above all, how you ensure that it is used properly and kept in working order. Many, many AFILS have been installed but now do not work because of neglect of this last subject. I hope, also, to touch on receiver design, for applications other than assisted hearing.

Appendix 1

Using an Oscilloscope to Measure Phase Angle, and thus Calculate the Inductance of a Loop

You may want to measure the inductance of a loop, rather than relying on the '2μH per metre of loop conductor' formula, if the loop goes up and over several doors etc., or there is steelwork in the building which may be increasing the inductance. Referring to Figure 14, you start by applying a 5kHz sine-wave signal to the amplifier input and adjust the signal level so that the amplifier is not overloaded. Then:

1. First, short-circuit the Y-input of the oscilloscope and mark the position of the zero-line on the screen (use wax pencil). Then connect the oscilloscope Y-input between A and B (Figure 14a), and adjust to display about 2 cycles of sine-wave. Use external trig/sync with a separate lead to A and B. Mark the zero-crossing points D, E on the screen (Figure 14b).
2. Keeping the oscilloscope synchronised to the voltage AB, transfer the Y-input to CB, and adjust the Y-GAIN (and SHIFT if necessary) *only* to display about the same height as before (not critical). Mark the new zero-crossing points (e.g. F in Figure 14c). Alternatively, if you have a double-or triple-beam scope, you can display both waveforms simultaneously, but keep the scope synched to the voltage signal.
3. The distance between zero-crossings of the two signals, such as DF in Figure 18c, divided by DE, is the phase angle θ between the loop voltage and current as a fraction of 180°. In the Figure:

$$\theta = DF/DE \times 180° = 60°$$

Thus, if the loop resistance measures $1{\cdot}1\Omega$ on your Maplin meter, the inductive reactance $X = 1{\cdot}1 \tan 60° = 1{\cdot}9\Omega$, and the inductance is $1{\cdot}9/(2\pi \times 5000) = 61\mu$H.

Appendix 2

Component Values for a Low-Level Passive Equaliser

It is convenient for this analysis to introduce the concept of 'normalised resistance' r_n of a loop, which is simply the ratio of its resistance to its inductive reactance at the upper -3dB frequency limit f_c of the system, normally 5kHz. Since both the resistance and inductance are proportional to the length of conductor, and the resistance is inversely proportional to the area of cross-section, the normalised resistance is simply inversely proportional to the cross-sectional area of the wire used for the loop! Using the relevant equations from Part 1,

$$R = 3{\cdot}6 \times 10^{-8}\, A/(\pi d^2/4)\ (\Omega)$$

and

$$L = 2A \times 10^{-6}\ (\mathrm{H})$$

where A is the length of wire in metres and d is its diameter, and taking the upper limit frequency as 5kHz,

$$r_n = 2{\cdot}82 \times 10^{-7}/(\pi d^2/4)$$

I have left the area of cross-section explicitly in the equation as $\pi d^2/4$ because the equation is most useful for wires specified in terms of area, such as house wiring cables. For example, $1\mathrm{mm}^2$ house wiring cable has a normalised resistance of 0·282.

The product of r_n and f_c gives the upper -3dB frequency achieved with that wire size, without corrective measures (series resistance, high or low-level equalisation, or current or intermediate drive). Thus for $1\mathrm{mm}^2$ cable, the upper frequency limit is 1413Hz, rather severely lacking in treble response!

For any loop, we can write:

$$I/V = 1/(r_n X + sL),$$

where $X = 2\pi f_c L$. Let $T = L/X$. Then:

$$I/V = 1/\{X(r_n + sT)\}$$

However, the required response (flat to f_c) is:

$$I/V = 1/\{X(1 + sT)\}$$

So, to obtain the required response from the actual response, it must be multiplied by $(r_n + sT)/(1 + sT)$, and this is the required response of the equaliser. Referring to Figure 16,

$$V_2/V_1 = R_2/\{R_2 + R_1(1 + sC)/sC\}$$

Let $R_1 = \alpha R_2$ and $\beta T = CR_2$. Then:

$$V_2/V_1 = (1/\alpha\beta + sT)/\{(1+\alpha)/\alpha\beta\} + sT\}$$

If α and β can be chosen so that $r_n = 1/\alpha\beta$ and $(1 + \alpha)/\alpha\beta = 1$, this expression is identical with the wanted multiplier. At zero frequency, if the expressions are identical:

$$\alpha = (1 - r_n)/r_n,$$

giving:

$$\beta = 1/(1 - r_n)$$

Luckily, this gives $(1 + \alpha)\alpha b = 1$, so the expressions are identical.

To use these results, we find r_n from the cable size and hence calculate α and β. Then:

$$R_1/R_2 = \alpha, \text{ and } R_2 = \beta/2\pi f_c C$$

Remember that you can choose C to be any convenient value.

Appendix 3

Power Dissipation in the Active Devices of a Class B Push-Pull Stage with Reactive Load

This analysis neglects the effects of saturation voltage in the devices, and resistors, such as emitter resistors, in series with the devices. To some extent, the small differences thus introduced cancel out anyway, except for valves (tubes), and I doubt whether anyone is going to make an AFILS amplifier with tubes!

Referring to the graphs of instantaneous voltage v and current i in Figure 17b, we have, adding the power dissipations in the two devices (or two sets of devices, if paralleled devices are used):

$$P_d = 1/\pi \int_0^{2\pi} vi\, d(\omega t)$$

$= 1/\pi$ x the sum of the integrals in regions 1, 2, 3 and 4. In regions 1 and 4, i is zero, so the integrals are zero. To simplify and generalise the equation, we express the peak output voltage as a fraction m of the maximum peak output voltage that the amplifier will produce, and the peak current (into the particular load impedance (magnitude) we are using) as the same fraction of the maximum peak current. This results in PF being expressed as a fraction of the product of peak voltage and peak current, i.e. of twice the maximum output power of the amplifier into the load impedance beihg considered. The other two regions then give:

$$\pi P_d = \int_\theta^\pi (1 - m\sin\omega t) m \sin(\omega t - \theta)\, d(\omega t) + \int_\pi^{\pi+\theta} m \sin(\omega t - \theta)\, d(\omega t)$$

The evaluation of these integrals is rather tedious: if anyone wants to see it, a note to the Kindly Editor would produce the goods, but the result is:

$$P_d = m/2\pi\{4 - m\cos(\pi - \theta) - m\sin\theta\}$$

This result applies for a constant magnitude of load impedance, with the phase-angle varying from 0° (purely resistive) to 90° (purely inductive or capacitive), and the results, for different values of m, are shown graphically in Figure 18.

CLASSIFIED

If you would like to place an advertisement in this section, here's your chance to tell Maplin's 200,000 customers 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 of charge. Thereafter the charge is 10p per word. Please note that only private individuals will be permitted to advertise. Commercial or trade advertising is strictly prohibited in the Maplin Magazine.

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For the next issue your advertisement must be in our hands by 1st December 1990.

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WANTED to purchase, walking model robots, or suitable ideas for construction of same including remote control etc. Correspondence to DIXON, 160 Goodrington Road, Paignton, Devon TQ4 7HX.

DOES ANYONE HAVE ANY 5600 SYNTHESISER PARTS tucked away gathering dust. PCB's, complete or incomplete modules, abandoned projects etc. If you have phone Robbie on Jersey 35097.

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INFORMATION on AYR Prestel adaptor model P1. I have the adaptor but not the remote control. Can anyone help, either with a diagram or remote? Please phone John (0202) 674612.

WANTED: Data sheet for 6522 VIA (used in BBC's) Original or Photocopy. Will pay for costs. 14 Sandringham Cres, East Herrington, Sunderland, Wearside SR3 3PT. Tel: (091) 5281333 after 4pm.

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SIX CHANNEL BURGLAR ALARM PANEL (Maplin YN57M). Includes external box, siren and battery back-up. £50. Tel: 0359 51258.

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LASER, finished 2mW He-Ne laser, uses Maplin tube, £100. Phone Pete on (0344) 23696 after 4pm.

MAPLIN LM59 speakers built to the book! (Pair), Technics SU Z11 amplifier, Toshiba PCG10 cassette deck for sale. All in v.g.c. Must be heard! Phone Gordon (0702) 711968 after 6pm.

ETI GRAPHIC EQUALISER £35. PE Orion 2020 Amp £25. Sony ST70 Tuner £25 or £75 the lot. All perfect condition and full working order. Will deliver locally! Chelmsford (0245) 450050 (home).

MARCONI TF801B SIGNAL GENERATOR 12-485MHz £30. AVO Signal Generator 50KHz – 80MHz £20. Tel: (0435) 830484 (East Sussex).

20MHz OSCILLOSCOPE (XJ61R) £200 ono 30V 3A PSU (XM41U) £85 ono. 1GHz Counter (MF82D) £60 ono. Digital Capacitance Meter (YT89W) £25 ono. All equipment hardly used. BBC 'B' with disc drive, monitor, etc; offers? 30 1mW He-Ne laser tubes, £40 each. Tel: (0252) 519037.

MUSICAL

MAPLIN 5600s Synthesiser for sale. Has been built but needs some work in setting up. Could be dismantled for parts. Any serious offers considered. Tel: (0293) 265019.

MES 53 organ, complete including 2 keyboards, speaker, pedalboard, stops and PCB's. All PCB's fully assembled but require wiring together and testing. £125 ono. Tel: (0302) 771200.

ORGAN CABINET, single manual portable, wooden legs, 5 octave keyboard fitted, never used, £50 ono. Also three octave keyboard (C-C), in metal case, £15. Durham (091) 385 4734.

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ONE 53 KEY, Computer Keyboard, 2 Voltmace Joysticks + Dragon 32 Software. 2 Medium sized Fidelity speakers. Contact Glen, 60 Grange Park Road, Leyton, London E10 5ES.

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HEATHKIT MICROPROCESSOR TRAINER, built and working, with manuals £120 ono. AIM 65, 6502 Microprocessor trainer and printer, working with manuals £120 ono. Epson FX80 printer, almost new £80. Tel: (021) 585 5698.

FOR SALE: 3½" 360K floppy drive with standard 34-way I/F £25. Stag 200W RMS Bass Cab with new speaker, £100, and colour Acorn Atom Computer £30. Phone Vince (0638) 663326.

BBC B, OPUS DOS, Speech Chips 6502 Second Processor, colour monitor, external ROM/RAM box, two disk drives, joysticks, games, books, bound magazine £425. Telephone (0752) 661364 evenings.

BARGAINS: TANDY TRS80 LEVEL II complete with expansion unit £50. Also DRAGON 32 £14. Pioneer PLD 12 Record Player £16. Soy Graphic Equaliser SEH22 £12. Wharfedale Receiver £15. UHER 4400 Tape Rec. £25. All working plus manuals. Telephone: (071) 582 7839

STAR LC10 PRINTER under one year old. Centronics interface plus spare ribbons. Will sell for £100 for quick sale. G.J. Eida, 14 Hurstwood Avenue, Bexley, Kent DA5 3PH. (0322) 522315.

WHAT IS SYSTEM X ANYWAY?

by Marion Hearfield

Part 2 – The Digital Exchange – How it Works

Photo 1. Front of System X rack cabinets.

Exchange Status	Maximum lines/ circuits	Maximum switched erlangs*	Maximum call-attempts per hour
Large international	85,000	20,000	400,000
Medium international	8,000	2,000	50,000
Large trunk	85,000 (60,000)	20,000 (25,000)	500,000 (1,000,000)
Large local	60,000 (100,000)	10,000 (25,000)	500,000 (800,000)
Medium local	10,000	2,000	80,000
Small local	2,000 (5,000)	160 (1,000)	8,000 (20,000)
Concentrator	2,000 (6,500)	160 (700)	8,000 (22,000)

*an erlang is defined as one line busy for one hour. It could be two lines busy for half-an-hour each, or ten lines busy for six minutes each (but that would be a bit inefficient).

Table 1. Traffic capacity.

I nearly called this article "The digital telephone exchange" – out of habit and familiarity I suppose. But of course the whole point of the new network is that it has been designed to carry voice and data, narrow-band and (eventually) wide-band, and it is more properly described as a communications network. New technology is again blurring the differences, and telephones are just one kind of terminal which can access the network.

The previous article described the need for a national digital comms network, its evolution, design principles and facilities. This article concentrates on how the modular, software-controlled, family of digital switches actually fit together and what they do.

One of the features of System X is its use of common channel signalling to replace the old analogue frequency division multiplexing. This may need explaining, so I'll do it now and get it out of the way. If you already know about it, skip a few paragraphs.

Common Channel Signalling – A Small Diversion

The use of common channel signalling enables much faster set-up times, and means that, during the course of a call, facilities such as call-transfer, call diversion, and all the rest, can be invoked.

Common-channel signalling (CCS), meets the international standard known as CCITT No.7. In CCS, information about the caller, the called, call progress and metering, is defined in a unique digital message. A common channel is dedicated to sending this message, together with messages defining other calls, thus providing signalling information for many separate voice/data channels. CCITT No.7 defines the different levels of signalling:

Level 1 specifies the bit rate (64Kbps), and the signalling information is bunched into messages, separated by flags.

Level 2 adds error detection, requesting re-transmission if necessary.

Level 3 adds codes which define the origin and destination of the call, plus the intermediate switch nodes along the route. The route is 'chosen' from a memory-based table, and takes account of any network problems. This level also provides system-management information about the moment-to-moment status of this part of the network.

Levels 4 and up carry the information needed to connect you to your

As well as meeting the CCITT 7 protocol, System X also copes with other protocols already in use, such as those covering packet switching and private networks.

Figure 1(a) and 1(b) illustrate the simplification available when using digital rather than analogue transmission and switching.

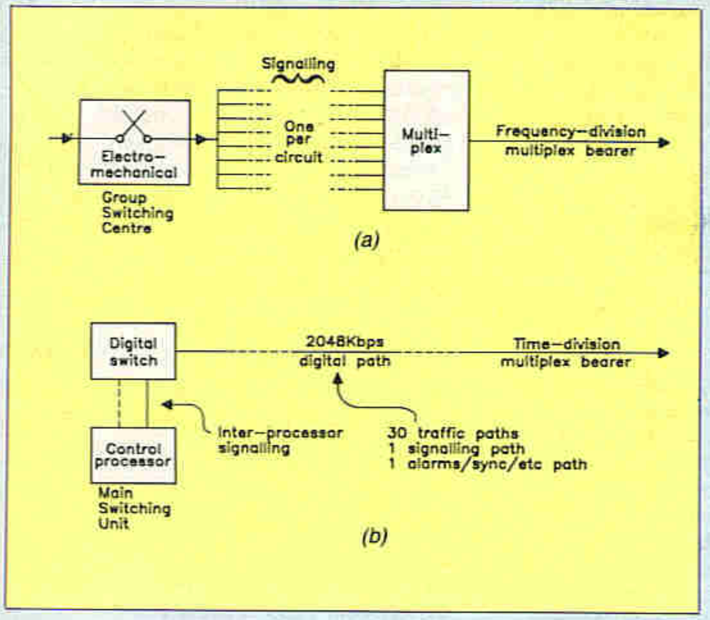

Figure 1a and 1b. Comparison of analogue and digital transmission and switching.

Photo 2. Front of System X rack with a card being removed.

Back to the Main Theme

By the late 1970's, modernisation of the U.K.'s telecomms network was long overdue. The existing network had been based on a pre-war technology, and piecemeal upgrading was no longer enough. A radical re-think was required. Digital transmission of both speech and data signals had become possible on a large scale, and reliable enough to be considered as the basis of the replacement comms network.

A range of differently-sized exchanges was planned, using identical hardware subassemblies which could be plugged together like Lego bricks to suit local requirements, and controlled by variable software modules.

Figure 2 illustrates this network structure, with concentrators (C) interfacing telephones, faxes, telexes, computer modems (M), to the trunk network (T) via the local exchange (L). Operators (O) are now connected at trunk exchanges, though they may be geographically separated from the actual exchange equipment by many miles.

The different sizes of exchange were planned to have the capacities shown in Table 1. The first sets of numbers are those originally envisaged; the numbers in brackets are those actually available to the UK network, according to GPT's most recent publications. Some of the changes are remarkable.

Since the whole philosophy of System X was that it should be modular, the actual size of each exchange is designed to suit local requirements.

For convenience in these articles, I have used the name System X (the British-made system supplied by GPT) as a synonym for all the U.K.'s digital exchanges, although a number of manufacturers are now involved.

Photos 1, 2 and 3 show what the exchanges look like – Photos 1 and 2 are photographs taken from the front of the suites, and Photo 3 shows what the back looks like without its tidy casing.

But how does a digital exchange actually work, what changes have been made to enable you access to the national digital network, and what is happening to the existing exchanges? We visited our local exchange to find out.

The Subscriber Concentrator – Small but Beautiful

Concentrators exist at the far-flung ends of the national telecomms system. They are the interface between the subscriber and the network, and provide terminations for all kinds of domestic or business telecomms and data equipment. They are usually connected by copper or fibre cables to the local exchange, but it is possible to have concentrators so remote that they are linked to the 'local exchange' via geostationary satellites!

It doesn't matter if your equipment is analogue or digital, or if you rent it from BT or bought it from the local newsagent. If it carries that little green circle the concentrator will process calls in and out, and cope with tone or pulse dialling, earth or loop calling, private metering, night busy switching; the works. The concentrator is also used by outstationed analogue or digital multiplexers for access to the main network.

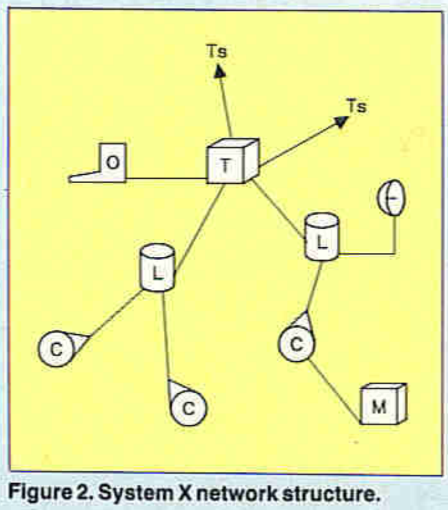

Figure 2. System X network structure.

Our small town only qualifies for a set of concentrators. The System X suites occupy less than 20% of the space used by the previous Strowger exchange. Now that the old racks have been stripped out (some of them being sold for re-use, the rest being scrapped) the original building is being used as a maintenance depot and store for the local BT vehicle fleet.

Each concentrator can output to a maximum of 240 lines connected to our nearest large town, where all the remaining call processing takes place. This is a good example of how the new network streamlines processing capability, and explains why our STD code changed too. The old autonomous local electro-mechanical exchanges, with their expensive and dedicated hardware, have been replaced by a much more flexible system. Calls from rural subscribers in a much larger geographical area are now channelled through local concentrators into the centralised facilities provided maybe 10-20 miles away. Of course, this means that my telephone call to a neighbour 200 yards away actually travels about 20 miles to get there. I could walk, of course, but it's raining.

Our local exchange channels about 12,500 lines into six concentrators. The necessary electronics are housed in four suites, each made up of six cabinets. Each cabinet is about 7ft. high x 30in. wide x 21in. deep, and contains six shelves. Two of the shelves carry the Subscriber Private Metering and other 'housekeeping' equipment, and subscriber linecards occupy the other four. The linecards themselves contain very few components – 3 DIL relays, about two dozen custom ICs, a few resistors, gas-discharge protection – on a card which measures 12ft. x 10in. x 1in.

There are three groups of line cards on each shelf; each group contains eight cards. Each line card contains all the electronics to handle eight subscriber lines and provides automatic gain setting, line balancing, and the A-to-D conversion via codecs.

Sorry about all the numbers, but they show how much physical space is being saved by the installation of these digital exchanges. 8 (subscribers) x 8 (linecards) x 3 (groups) = 192 subscribers per shelf.

That is, 192 subscriber terminations now occupy a space approximately 30in. x 12in. x 10in., which is about the same as a small bookshelf containing 40 Maplin catalogues. The equivalent activity (excluding any A-to-D conversion, or course) in an electro-mechanical exchange occupied a space of about 160in. x 242in. x 6in., which was more than six times bigger. The chap in Photo 4 is dismantling an old uniselector, and we will not see the like of it again.

To put its size in perspective, all the equipment needed for a 5,000-line small local digital exchange can be delivered in one 30ft. container.

Subscriber and Network Cabling

The links between our local exchange and the next one up the line are provided by an equal mixture of (existing) copper – carrying 30 PCM channels – and (newly installed) optical fibre.

(Did you know that every copper cable under the ground is enclosed in an airtight sheath and compressed air is pumped through to keep water out if there is a break in the sheath? I didn't, until I saw the gauges in the exchange. The cable air pressure is monitored constantly and any reduction in pressure will eventually result in a road being dug up to repair the damage!)

Copper pairs are difficult and expensive to maintain, and the bandwidth is limited. Although it is claimed that as many as 10 digital voice channels can be carried on a single pair, most PTTs assume that the ISDN bit rate of 144Kbps is a more practical limit. And although copper cable has a long life, it is prone to faults, signal loss, and water, and existing links are gradually being replaced by optical fibre.

In November 1985, it was expected that by 1988 40% of trunk traffic would be carried over fibre-optic lines, with promised major cuts in phone charges. Has anyone noticed a price reduction? Cost reductions were supposed to result from fewer maintenance staff being needed, and by the downward trend in the costs of fibre. The cost of fibre-optic lines has dropped substantially over the past few years, and now is near the cost-per-kilometre of copper lines.

BT has already started laying fibre directly to large business customers (say above 25 lines), in an overlay network of 96-fibre cables, split into 48- or 24-cable links to a joint common to several customers.

This is not economic for smaller subscribers, although BT is now experimenting with fibre in the local loop which connects clients premises to local exchanges. Such cabling would be capable of carrying voice, data, stereo television and radio traffic, though at present BT is not normally allowed to carry television channels. BT has announced that it will be spending £5million on a trial installation in Bishop's Stortford, although a similar experiment in France has been quietly allowed to die because the local subscribers were not making enough use of the facility to make the installation economical.

Power

Each suite of exchange cabinets contains its own backup sealed batteries and rectifiers. As a suite is added to extend the exchange's capability, its backup power is also automatically included. These batteries need no regular maintenance. Gone are the days of separate large battery rooms in each exchange, with their memorable instructions (according to an engineer of my acquaintance) "All water used to top up these batteries must have been passed by the Assistant Engineer". Three-phase mains comes straight into each rack. The batteries provide one hour of support; a longer power outage is covered by a local diesel generator.

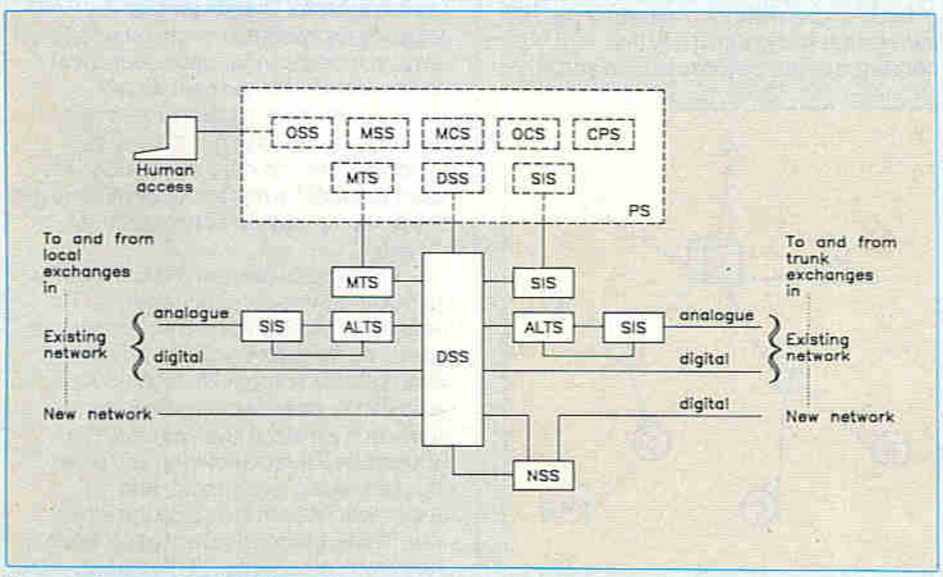

Figure 3. System X switching subsystem architecture.

The System Architecture beyond the local Concentrators

Once your call has passed through a local concentrator, it will enter the digital network proper. All subsequent call switching and transmission goes through a series of whichever larger and larger installations are necessary to route your call to (eventually) your destination's concentrator, and hence to your mum.

Modular assembly results in the different sizes of exchange already mentioned and shown in Table 1. A small local exchange (up to 5,000 lines) can support small concentrators and multiplexers. Although it is designed to operate unattended, it can offer full operator facilities based at the trunk exchange, and is monitored remotely for traffic statistics, fault analysis, and other management information collected further up the line. Larger exchanges are (nearly) just more of the same, plugged together.

So what are these modules? Figure 3 shows the switching subsystem architecture and these modules, plus the over-riding control systems, are described next.

The Hardware

The controlling heart of the digital switch is the PROCESSOR. Because of System X's inherent ISDN capability, the designers knew that there would be a great increase in the number of call attempts caused by the inclusion of data transmissions. Unlike voice links, data can be sent in very frequent, very short bursts. But each data transmission is still a call, as far as the switch is concerned, and has to be handled just like a voice transmission.

Each System X processor was therefore designed to cope with up to one million busy hour call attempts (BHCAs) and more if needed. It achieves this processing power by using standard components in an unusual architecture, in which up to four central processing units are close-coupled, sharing common memory. These clusters, as they are called, can then be loose-coupled in a group of up to eight clusters – such a switch size would handle 2 million BHCAs.

The CENTRAL PROCESSOR UNIT CLUSTER processes all the information needed to pass a call through the exchange. It introduces great flexibility in handling; for instance it can dictate changes to line allocations, so that known heavily used lines are allocated greater access to concentrator. Always under the control of an operating system, the CPU runs background maintenance and diagnostic checks in between processing calls. In the event of a CPU failure, the remaining CPUs in the cluster can maintain service because they have common memory access.

The DIGITAL SWITCH connects all the subsystems. Its main function is to switch 64Kbps paths, although it is also capable of switching up to 34Mbps. It handles common-channel signalling, and interworking signalling from the remaining analogue exchanges. All signal path setups are decided by an internal microprocessor and are then duplicated within the switch. This ensures continuity of service in the event of path failure.

The PROCESSOR SUBSYSTEM (PS in Figure 3) decides the operation of the various subsystems, using software programs to control call processing, system overload and maintenance, and generates management and operations statistics.

The SUBSCRIBER SWITCHING SUBSYSTEM (SSS) accepts and analyses incoming calls, and concentrates them into high-traffic common circuits at the local exchange.

The DIGITAL SWITCHING SUBSYSTEM (DSS) interconnects these circuits.

The MESSAGE TRANSMISSION SUBSYSTEM (MTS) carries out common-channel signalling functions, and provides error correction. The modules use normally two, sometimes four, signalling links, routed via a spare timeslot (usually TS16). In heavy traffic signalling messages are repeated to ensure their transmission, and the whole module operates within a choice of three hardware routes, to minimise loss or failure. In light traffic, the unit transmits signals which allow synchronisation to be checked and gives local status information. Analogue signalling links terminate here, via modems.

Not only are outgoing and incoming messages queued here, but message information is stored in case any internal signalling link fails. In this case, the information is re-transmitted over one of the alternative internal links.

Voice transmission, by its nature, contains redundancies. Synchronisation is not as critical, since some information can be lost without the (human) receiver noticing any difference.

But synchronisation is essential in a network which carries data, since loss of even one piece of information could turn the message into garbage. To avoid this, one of the modules is responsible for keeping the exchange 2·048MHz master clock in synchronisation first with other master clocks and ultimately with the reference clock for the whole network. As a back-up, System X provides buffer stores at the receiving end of each link, so a small amount of drift, either phase or frequency, is catered for.

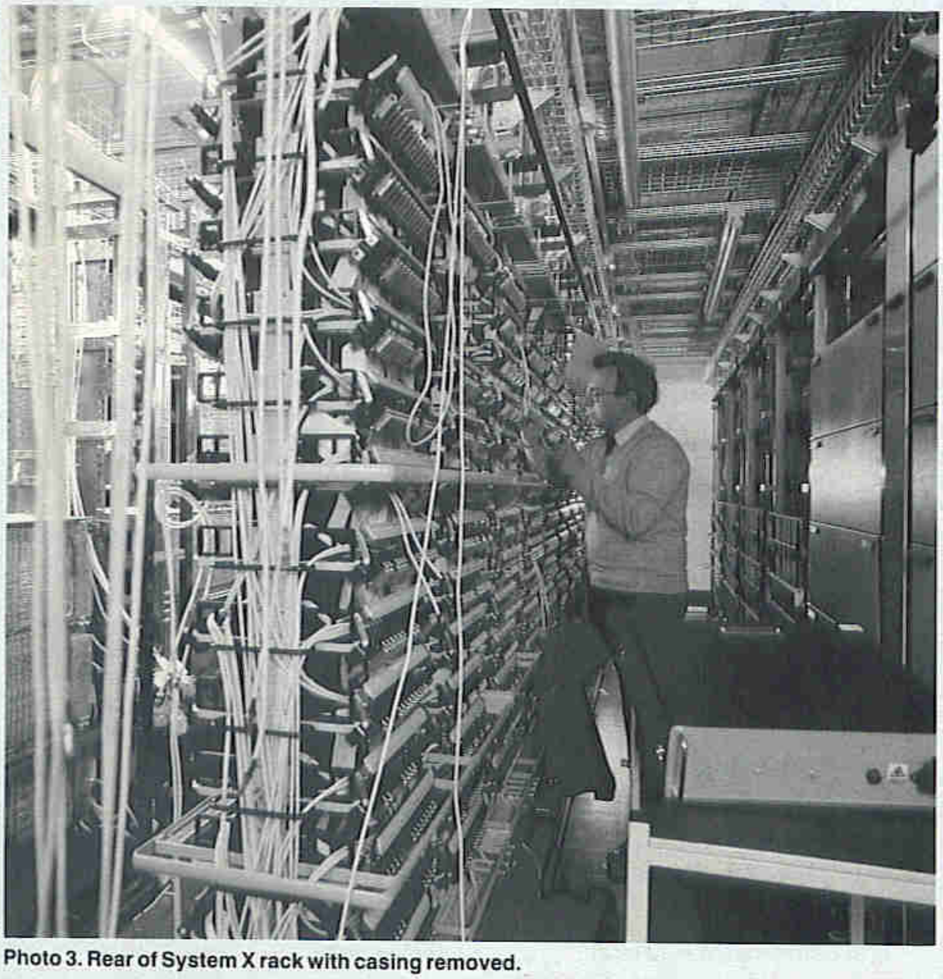

Photo 3. Rear of System X rack with casing removed.

The SIGNALLING INTERWORKING SUBSYSTEM (SIS) interfaces the exchange to the different signalling systems in other types of exchange, with the exception of MF, which is terminated separately but in a similar way.

This subsystem also provides recorded announcements and standard tones.

Incoming signals are converted to TS16 format for analysis and processing, and up to 900 circuits can be handled by each TS16 unit.

The ANALOGUE LINE TERMINATING SUBSYSTEM (ALTS) converts analogue transmission signals into a digital format, and digital to analogue, to allow existing analogue exchanges to be used until they are replaced by digital systems.

The NETWORK SYNCHRONISATION SUBSYSTEM (NSS) ensures that the exchange operates within the binary rate tolerance of the network.

The Software

The software used in the network is also modular, under the control of a central operating system which allocates time and storage to the various applications modules, and acts as timekeeper and messenger.

The CENTRAL PROCESSOR UNIT controls the working of all the software subsystem processes on the basis of priority. Each process can be in one of five states:

RUNNING (being carried out by the CPU)
SUSPENDED/INTERRUPTED (paused, for higher priority processing)
SUSPENDED/UNBLOCKED (waiting for space on the CPU)
BLOCKED (process has finished)
TRAPPED (fault prevents further operation).

The CPU deals with one process at a time. At any time it can be instructed to suspend and store – 'nest' – the activity because a higher priority process is ready to be dealt with. By constantly monitoring the priority of suspended processes, and dealing with the highest first, the CPU is designed to handle all the subsystems with efficiency and maximum throughput. And, unlike humans operating under these conditions, the CPU actually does get those lowest priority jobs done!

The CALL PROCESSING SUBSYSTEM (CPS) deals with network routing, route selection, route supervision, numbering, control of user facilities.

The CPS receives and stores the incoming message (from the MTS), earmarks an area of memory for a call supervision record, and requests the DSS to connect the incoming circuit to an outgoing one. When the circuit is completed, the message is erased, although the call supervision continues until the circuit is cleared.

The OVERLOAD CONTROL SUBSYSTEM (OCS) monitors processor activity. Abnormal overloads could cause failure in the central processor, or problems in the network. If the number of call attempts is more than the processor can handle, newly-arriving calls can be rejected instead of being allowed to clog up the queues. This means that the number of successful calls – those already in the queue – is maintained at an optimum level, and a greater throughput is achieved. Successful connections earn money; rejected callers will usually try again.

The MANAGEMENT STATISTICS SUBSYSTEM (MSS) interfaces with other subsystems to collect information for later analysis on such useful parameters as traffic intensity, route usage, call failure, calls in different tariff bands, and local congestion.

The MAINTENANCE CONTROL SUBSYSTEM (MCS) monitors the system's operation, identifies actual or possible faults, isolates faulty sections and generates reports for maintenance staff. A number of automatic tests can be generated, including checking subscriber lines and exchange interconnections.

The OPERATOR SUBSYSTEM (OSS) enables operators and maintenance staff to communicate with the system, and supports printers and data links for the system to 'talk' back.

Even System X still needs human beings occasionally. Operators now work in normal offices, and they can be some distance away from the main exchange. After all, why pay for prime city-centre office space when the technology allows them to be out-stationed, maybe even with a view of trees rather than traffic? Their work is controlled and presented by an operator services subsystem, which allocates priorities to all incoming calls. Each operator has a monitor, a keyboard, and a headset, and full details of the next call are presented on-screen (and to the headset) by the operator services subsystem. The operator initially has access to all the facilities likely to be required by the caller, and the software is designed to make processing a call as quick and efficient as possible.

The receipt of an emergency call, for instance, will produce a list of all the possible local emergency service names and telephone numbers; the operator simply selects the correct service from the menu and the system takes over the job of connecting the caller.

Processing directory enquiries has also been automated to a greater extent than before. The operator has access to the database of telephone numbers; once the required number is located on the screen, the tap of a key frees the operator to take the next call, and invokes a recorder voice which clearly and patiently tells us the number we want.

Other databases exist. The operator can enter an exchange name, and the system will translate this into its dialling code. Freephone names are similarly translated automatically. And if your telephone credit card is invalid, the operator will soon find out.

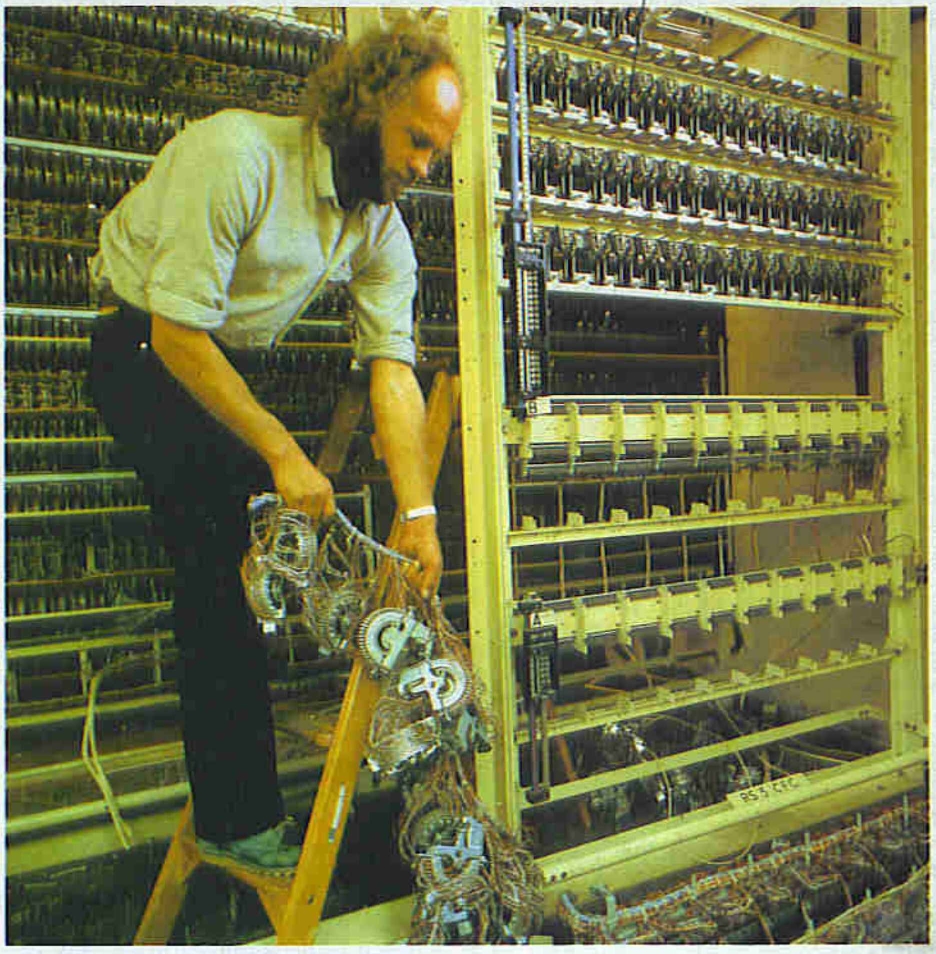

Photo 4. Removal of old uniselector.

Network Upgrading

The modular structure enables enhancement of specific subsystems without disturbing the rest of the network. Since so much of the network is software-controlled, system upgrades tend to be in the software rather than the hardware.

Upgrades are already being installed. The most noticeable improvement has been in the reduced time taken to restore service after a CPU crash. Early systems had to re-program each concentrator in sequence – based on PROMs, re-programming each concentrator took about 10 minutes and it could be hours before all the concentrators controlled by the CPU were ready. Newer systems re-program all the concentrators in parallel and the local network can be up and running again in about 30 minutes. CPU crashes do happen, although the stability inherent in the design more than meets the national standards.

System Maintenance

Test and maintenance is monitored and controlled at regional centres (ours is done via a VAX in Bristol) with access via a terminal in each local exchange. So access to 'our' CPU at Gloucester is via a data link to the Vax in Bristol, and a further link back to Gloucester.

In the old electro-mechanical exchanges, the worst that could happen was a total exchange power failure, which was almost unheard of. The weakness of the new network is that a software fault could, in the worst case, affect subscribers in a much larger catchment area. In practice however, an accumulation of faults should result in a controlled reduction of quality of service, rather than a system shutdown.

Our local BT maintenance engineer was however pleased with the reliability of our exchange. It has a very low failure rate, and he had only made four maintenance visits in the three months before our visit. The exchange 'spares' – three spare line cards and one of everything else – are kept in one cupboard!

So, is Digital Desirable?

It certainly seems to be user-friendly, flexible and reliable. Many of the items on my personal wish-list for communicating with the outside world are now available. But there is still one at the very top of the list – when will an ordinary domestic telephone tell me who is calling BEFORE I pick up the handset.

Acknowledgement

Thanks are due to BT and GPT for providing some of the technical information contained in this article, and to the BT Picture Library for the photographs.

A readers forum for your views and comments. If you want to contribute, write to: **The Editor, 'Electronics – The Maplin Magazine' P.O. Box 3, Rayleigh, Essex, SS6 8LR.**

AIR YOUR VIEWS

Dear Editor

Sky Flies High?

Dear Sirs,
I was surprised that you don't check up on the information supplied by advertisers. I assume that the article was supplied by the PR department of Sky and printed without any question? Perhaps in your next issue you will correct some of the glaring errors from your article. I would suggest that you point out that Sky is probably worse than a terrestrial based station for repeats and choice. On a typical Sunday tea-time the three non-subscription channels of Sky may well have Sport (Cricket on Sky One), Sport (on Sky Sport) and Sport News (on Sky News). At the same time of day the only other non-subscription channel transmitting, MTV, has teenager orientated Pop Music. The only other non-subscription channel, The Children's Channel, only transmits in the mornings. The remaining English language channels, Screensport and the afternoons only Lifestyle, are both subscription channels. Unfortunately, housewives cannot subscribe to Lifestyle. The only way to obtain it is to subscribe to Screensport and get it free in the package. This is no doubt a very good offer for the ladies (I don't think)! The rest of the programmes have French or German or Scandinavian or even Japanese sound or don't use PAL or they're scrambled for all or part of the day. What an offer! And as for the next sixteen channels on Astra 1B. There's a rumour that Super Channel and Discovery might be there. Maybe even BBC Europe, but scrambled. The rest won't be English. That's nothing like the rosy picture your article paints, by any means, is it? But despite it all, there is some good news for British expatriates, BBC is supposed to be trying to find a DTH satellite. When I phoned TeleClub to ask if they were going to be able to send original and dubbed sound on films, as they have four sound channels available (they said no!), they did say that only one American film distributor is hanging out to prevent Sky and others selling decoders to British Nationals and British Servicemen abroad and that after 1992 it might even be illegal to discriminate on grounds of nationality! Until then – thank goodness that Intelsat 6 comes in with a 1m2 dish! Hoping to read something more accurate in future.
Peter Bendall, Germany.
P.S. When my daughter's Astra System was installed in UK last month, the installer asked if she could understand German? "You'll need it" he said. He's right, there's lots more in German.

Thank you for your comments, however your assumption that the article was supplied by Sky TV's PR department is incorrect. The article was researched and written by our consultant author Alan Simpson, who also writes for several daily newspapers. Everyone is entitled to their own purely subjective tastes in viewing, if you don't like the programmes, you don't have to watch them. You may be interested to know that Maplin have introduced a new range of satellite systems; with a choice of dish sizes and LNB's, complete with fully steerable mount. These systems will receive most of the European satellites, including Astra, that way you get the best of both worlds, good idea eh!

S·T·A·R L·E·T·T·E·R

This issue, R. Follet from Berkshire receives the Star Letter Award of a £5 Maplin Gift Token for his letter on Video Projects.

Video Projects Please

Dear Sir,
You will appreciate that this letter is motivated by my own selfish wants, but I would like to suggest an area of activity to be included in the Maplin Magazine. If I was to pick one aspect of the Maplin Magazine that I like it must be that when you pick a subject you do it in-depth and in a manner that is easily understood. My interest is video photography and I would like to know about and indeed construct the following.
1. How does a Timebase corrector (TBC) work. Why are they so costly (upwards of a £1000).
2. What is needed to make a broadcast spec PAL encoder taking an analogue RGB input (£3000).
3. Genlock. How can a computer/video recorder/camera be genlocked (all prices).
4. How to construct a frame; store mixer. This would overcome the need for genlocked sources, also other effects would be applied at this stage (£1000 upwards).
From the above list you will note that each one is very expensive to buy and I do not know why, it cannot be component cost. A series of in depth articles followed by constructional details would make me very happy! I am aware that you can only consider articles that a high percentage of your readership would find interesting and construction kits must be a viable proposition. But there is an increasing number of camera owners and some of them will be readers.

What better motive to build a project than 'it's cheaper'? Thank you for some good suggestions, they've been passed onto 'the back room boys' in the lab.

Kit Ideas in Print

Dear Sir,
I am an avid kit builder and computer user, and I have found printer buffers drastically overpriced. So, I would like to suggest that you bring a parallel printer buffer onto your range of projects and modules. Lastly, well done Maplin for getting your Cashtel system working, though a few more lines would be useful.
A. Howat, Southport.

What a good idea! Obviously the bulk of the project cost is contained in the RAM IC's (prices of RAM IC's are index linked to the international rice index), even so, a project offering the facilities found on commercial printer buffers would be reasonably priced. I will make use of our new internal memo system to let the 'lads in the lab' know about the suggestion. Now where did I leave my mallet, chisel and stone tablet?

Current Confusion

Dear Sir,
Don't you think your 'Square One' article is a little confusing for beginners? Mr Dixey states "It doesn't actually matter that much which direction is assumed for current flow...". I feel I must disagree. It is important that electronic engineers work to established standards. It would make work among engineers almost impossible if some insist on using conventional notation, while others use electron flow. Imagine the chaos if one engineer started a project, and then handed it over to another for completion, and both used different means of notating their diagrams.
Virtually all text books use conventional current flow as the standard for indicating direction of flow. Take a look at the diagrams in your 'Switched Mode Power Conversion' series. Any good engineer will immediately recognise what the arrows indicate – I doubt if this would be the case if the arrow-heads were reversed.
It is important that those setting out in electronics establish good practise from the start. By 'convention', we use 'Conventional Current' in diagrams.
B. Adams, Co. Antrim.

Comment noted! We certainly agree that virtually all text books and engineers use conventional current flow and we hope that the comment hasn't caused too much confusion. After all, the name conventional current flow immediately implies that it is the standard convention. However we would like to make two points, it is as well to know that the ACTUAL direction of electron current flow is opposite to that of conventional current flow; especially when examining the principle of operation of semiconductor devices, e.g. BJT's, FET's, etc. Also, that once most people are 'in the know', they will quite happily swap between the two, as and when the situation dictates. Otherwise it would be a bit like ignoring the fact that the continentals drive on the opposite side of the road!

Oh, What a Bind!

Dear Sir,
Electronics No. 39 duly arrived and I really must congratulate you on the general tenor of the contents. It gets better every month; BUT it's getting so good I'll be keeping them for reference: may even bind them . . . and yet you ask the reader to ruin it by putting the Order

AIR YOUR VIEWS

Coupon on one side of a sheet, and an important part of a good article on it's back side. If the order form is used, the article is ruined. Why not print an order form (if you must) and print on the back side somehow less important 'articles' – e.g. the cure for indigestion and classifieds which won't be important after a week or so. By the way, a TRUE story. Remember the pre-war joke of "they laughed at me when I sat down and played the Moonlight Sonata" – now modified to ". . . until they saw my logbook". Well I recently bought an expensive transceiver. The sales person said "we like to know a little about our customers, what technical magazine do you prefer?" 'Electronics – The Maplin Magazine' says I. He laughed until. . .

Anon.

We do not want you to have to cut up important articles either! Wherever possible we try to ensure that coupons, etc, do not back onto feature articles or projects. Unfortunately, it doesn't always work out that way. You also mentioned binding your magazines; I am sure that you will be pleased to learn that top quality 'Electronics' binders are now available for only £5.25 and to coin a phrase 'not a lot of people know that!'. Full details of the binders can be found on the inside front cover of this issue.

Swiss Swizz

Dear Sir,

Watch batteries – I recently needed a new battery for a cheap digital watch and at a local jeweller was charged £2.50 for the replacement to fit myself. Thinking this excessive for a small silver battery, I looked up the price of an equivalent in the Maplin Catalogue. It was 20 pence!! The explanation given by the jeweller when I complained was that he only supplies "high-class leak-proof Swiss-made batteries", whereas the catalogue equivalents are "Hong Kong junk" – his words. I find this hard to believe and would like to know whether there are large quality differences in such a simple battery or are the jewellers perpetrating an enormous rip-off on an unsuspecting public? At another jeweller in the same town I was asked for £3 but this did include fitting. The Swiss battery supplied was a Renata 364; the Maplin an SG1. These are both equivalent to the original US-made RW320.

J. Bolton, Herts.

A major consideration of the price differential is due to the purchasing power that Maplin has and the high turnover of battery stock, we buy batteries in 4-figure quantities direct from the manufacturer. In contrast your local jeweller will have a dramatically lower turnover of battery stock, probably only buying ten or twenty batteries at a time from a wholesaler or distributor, who in turn obtains their supplies from an importer. It is clearly a case of cutting out the middle man, consequently the saving is passed directly onto you, the customer. I am sure that most people will agree that Swiss watch engineering is the best in the world; but when it comes down to basics, the active chemical in a silver-oxide battery is the same wherever the battery is made.

Syntom Revisited

Dear Sir,

I was pleased to see the return of the Syntom Drum Synthesiser project in the June-July issue of 'Electronics' magazine and was hoping to see an improvement to overcome the only annoying feature of the unit. Although the Syntom has many and varied settings you can't do a progression down through pitch levels as you can with a real drum kit, since there is only one trigger and you have to keep stopping to change the pitch. The obvious solution to this problem is to build several Syntoms, but cost is a major drawback. I was wondering whether someone may have come up with a system of having, say, 4 triggers connected to one main Syntom where each trigger caused a different pitch to be produced. Unfortunately there were only minor improvements. Perhaps one of your experts could have a go?

T. Field, Gillingham, Kent.

The Syntom, although republished, has not been drastically modified and the single trigger input is inherent in the design. It was originally intended that rather than designing an 'all singing all dancing' multi-drum unit, a simple and cheap single unit could be designed. Then, if drummers wanted multiple drum setups, several units could be built at reasonable cost. If we publish a new electronic drum synthesiser, we will incorporate the latest digital techniques and include a MIDI interface and utilise sampled drum sounds rather than using synthesis techniques. If any readers have suggestions for electronic musical projects, MIDI projects, etc., please write in.

MAPLIN'S TOP TWENTY KITS

POSITION			DESCRIPTION OF KIT	ORDER AS	PRICE	DETAILS IN		
1.	(1)		MOSFET Amplifier	LW51F	£19.95	Magazine	41	(XA41U)
2.	(2)		Digital Watch	FS18U	£ 1.98	Catalogue	'91	(CA08J)
3.	(3)		Live Wire Detector	LK63T	£ 3.95	Projects	14	(XA14Q)
4.	(4)		Car Battery Monitor	LK42V	£ 8.95	Magazine	37	(XA37S)
5.	(8)		LM386 Amplifier	LM76H	£ 3.75	Magazine	29	(XA29G)
6.	(5)		I/R Prox. Detector	LM13P	£ 9.95	Projects	20	(XA20W)
7.	(11)		U/Sonic Car Alarm	LK75S	£19.95	Projects	15	(XA15R)
8.	(6)		Car Burglar Alarm	LW78K	£ 9.95	Best of Book	2	(XC02C)
9.	(10)		8W Amplifier	LW36P	£ 5.95	Catalogue	'91	(CA08J)
10.	(7)		PWM Motor Driver	LK54J	£ 9.95	Projects	12	(XA12N)
11.	(16)		TDA2822 Amplifier	LP03D	£ 6.45	Magazine	34	(XA34M)
12.	(12)		TDA7000 Radio MkII	LM55K	£19.95	Magazine	27	(XA27E)
13.	(20)		Watt Watcher	LM57M	£ 3.95	Magazine	27	(XA27E)
14.	(14)		Mini Metal Detector	LM35Q	£ 5.25	Magazine	25	(XA25C)
15.	(15)		Car Digital Tacho	LK79L	£19.95	Magazine	37	(XA37S)
16.	(19)		Laser & PSU	LM72P	£99.95	Magazine	25	(XA29G)
17.	(13)		Siren Sound Generator	LM42V	£ 4.25	Magazine	26	(XA26D)
18.	(17)		15W Amplifier	YQ43W	£ 6.75	Catalogue	'91	(CA08J)
19.	(9)		Partylite	LW93B	£ 9.95	Catalogue	'91	(CA08J)
20.	(–)	RE-ENTRY	Rec/Playback	LM80B	£36.95	Magazine	30	(XA30H)

Over 150 other kits also available. All kits supplied with instructions.

The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.

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3 NO CHANGE

IC555 Projects, by E.A. Parr *(LY04E) Cat. P78.* Previous Position 3. **Price £2.95.**

4

A Concise Advanced User's Guide to MS-DOS, by N. Kantaris. *(WS44X) Cat. P91.* Previous Position: 5. **Price £2.95.**

5 NEW ENTRY

The Maplin Electronic Circuits Handbook, by Michael Tooley. *(WT02C) Cat. P75.* Previous Position: New Entry. **Price £10.95.**

6

Power Supply Projects, by R.A. Penfold. *(XW52G) Cat. P77.* Previous Position: 4. **Price £2.50.**

7

International Transistor Ealents Guide, by Adrian Michae *(WG30H) Cat. P70.* Previ Position: 8. **Price £3.95.**

8

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Electronic Securites by R.A. Penfold. *(RL43W)* 7. Previous Position: 9. **Price**

10

More Advanced Power Supply Projects, by R.A. Penfold. *(WP92A) Cat. P77.* Previous Position: 7. **Price £2.95.**

11

Remote Control Handbook, by Owen Bishop. *(WS23A) Cat. P77.* Previous Position: 10. **Price £3.95.**

12 NO CHANGE

An Introduction to Loudspeakers and Enclosure Design, by V. Capel. *(WS31J) Cat. P80.* Previous Position: 12. **Price £2.95.**

13 NO CHANGE

Practical MIDI Handbook, by R.A. Penfold. *(WP96E) Cat. P82.* Previous Position: 13. **Price £5.95.**

14 NO CHANGE

How to Use Op-Amps, by E.A. Parr. *(WA29G) Cat. P73.* Previous Position: 14. **Price £2.95.**

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A Concise Introduction to MS-DOS, by N. Kantaris. *(WS94C) Cat. P91.* Previous Position: New Entry. **Price £2.95.**

16

How to Design and Make Your Own PCB's by R.A. Penfold *(WK63T) Cat. P73.* Previous Position: 17. **Price £2.50.**

17 NEW ENTRY

How to Expand, Modify and Repair PC's and Compatibles, by R.A. Penfold. *(WX95D) Cat. P93.* Previous Position: New Entry. **Price £4.95.**

18 RE-ENTRY

Radio Amateurs Examination Manual, by G.L. Benbow. *(WP87U) Cat. P83.* Previous Position: Re-Entry. **Price £5.65.**

19 NO CHANGE

Mastering Electronics, by John Watson. *(WM60Q) Cat. P74.* Previous Position: 19. **Price £4.50.**

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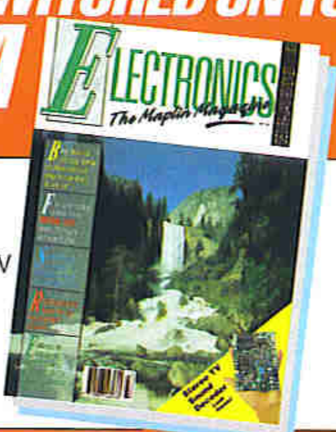

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