No 39

AUG-SEP '90 · £1.20

IR £1.76

ELECTRONICS

The Maplin Magazine

08

9 770957 545015

TMS77C82 Microcontroller • Build an **AFSK GENERATOR** • Data File: **SSM2015 Microphone Preamplifier** • **WIN a SKY TV SATELLITE RECEIVER SYSTEM** • **MINI CIRCUITS** from **Bob Penfold** • Read all about **DISK DRIVES** and **INDUCTION LOOPS.**

CONTENTS

AUGUST TO SEPTEMBER 1990 VOL.9 No.39

EDITORIAL

Hello! And welcome to another edition of *'Electronics – The Maplin Magazine'*. Presented in this issue is part two of the truly superb NICAM Stereo TV Tuner Unit with details of an astonishing special price deal for the complete kit! There's the start of a much requested series on Audio Frequency Induction Loop Systems. By popular demand Bob Penfold returns with more of his ingenious Mini Circuits. Alan Simpson reports from the studios of Sky TV; you may even win a Sky TV Satellite System in this issue's competition! The next part in the series on radioteletype is an Audio Frequency Shift Keying Generator. Graham Dixey takes us back to Square One with the next instalment of his beginners series. The SSM2015 microphone pre-amplifier will appeal to anyone who uses low-impedance microphones. If you have ever wondered how computer data is stored on disk, then read Computers in the Real World. In the near future projects will be appearing which make use of the TMS77C82 micro-controller, Tony Bricknell delves inside this extremely flexible 'self contained computer' chip and reveals its secrets. The concluding part of Switched Mode Power Conversion deals with the remaining converter topologies and looks at the operation of a complete power supply. And of course there's all the usual regulars. So why not read on and enjoy!

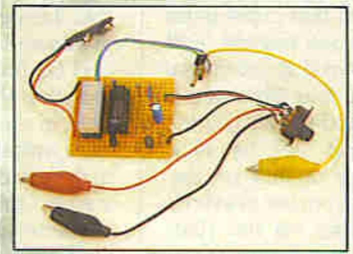
R. T. Smith

Editor Roy Smith **Technical Editors** Dave Goodman, Chris Barlow, Gavin Cheeseman, Tony Bricknell, Allan Williamson
Technical Author Robert Ball
Consultant Author Alan Simpson
Technical Artists John Dudley, Lesley Foster, Paul Evans, Ross Nisbet
Art Directors Peter Blackmore, Jim Bowler
Art Assistants Eugene Francis, Phillip Fey, Mick McGurk
Print Co-ordinators Brian Lauezzari, Martin Needs, Ken Wakefield, Paul Owen
Published by Maplin Electronics plc.
Typesetting by Inline Design Systems Ltd., 258a London Road, Hadleigh, Benfleet, Essex SS7 2DE
Colour Separations by Stirling Graphics Ltd. 16-22 West St., Southend, Essex SS2 6HJ.
Printed by SVP, Caerphilly, Mid Glam. CF8 3SU.
Distributed by United Magazine Distribution Ltd., 1-11 Benwell Rd, London N7 7AX.
Mail Order P.O. Box 3, Rayleigh, Essex SS6 8LR.
Telephone Retail Sales: (0702) 554161. Retail Enquiries: (0702) 552911. **Trade Sales:** (0702) 554171.
Cashtel: (0702) 552941. **General:** (0702) 554155.
Fax: (0702) 553935. **Telex:** 995695.

PROJECTS

2 BOB'S MINI CIRCUITS

Another collection of novel experimenters circuits from Robert Penfold.



17 NICAM STEREO TV TUNER UNIT

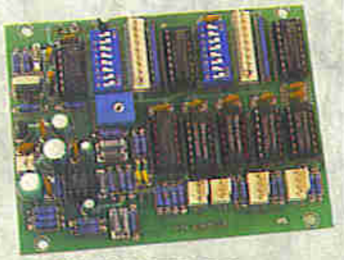
Part two of a project on how to build a full-function stand-alone NICAM Stereo TV Tuner Unit.

40 DATA FILE: SSM2015

Data File this issue presents a high-quality very low noise microphone pre-amplifier.

48 AFSK GENERATOR

Part four in the series on receiving and transmitting RTTY (radioteletype).



56 TMS77C82 MICRO-CONTROLLER

Part one introducing the Texas Instruments TMS77C82 micro-controller.

FEATURES

8 SQUARE ONE

Part three in this beginners series looks at resistance, reactance and impedance; phase; amplifier input and output impedances; FET's, test equipment and also presents a design for a bench power supply unit.

25 COMPUTERS IN THE REAL WORLD

Part seven deals with magnetic recording principles; covering both hard and floppy disk systems.

32 SKY FLIES HIGH

Our roving reporter takes a trip to the Sky TV Studios in London and gives you the opportunity to win a Sky TV satellite system!

35 AUDIO FREQUENCY INDUCTION LOOP SYSTEMS

Part one in an authoritative series about Audio Frequency Induction Loop Systems, which deals with both the theory and practice, and also dispels some common myths.

44 SWITCHED MODE POWER CONVERSION

The concluding part deals with the push pull converter, the half and full bridge converter and looks at a mains operated switch mode power supply.

REGULARS

CORRIGENDA

Issue 38, Computers in the Real World part 6:

The caption to Figure 6 on page 63 is incorrect . . . (addresses C000H – C007H inc.) . . . should read . . . (addresses C000H, C050H, C0A0H, C0F0H, C140H, C190H, C1E0H and C230H).

Issue 36, SP0256 Speech Synthesiser (LP10L)

Some customers have experienced problems with this project due to low power supply voltage to the SP0256 IC. Because of the voltage drop developed across the protection diode, D1, the supply voltage may, in a few cases, drop below the minimum level required for the IC to operate reliably. If problems are experienced then D1 should be replaced with a wire link. After modification special care must be taken to ensure that the power supply polarity is correctly observed, otherwise damage will occur.

Copyright. All material is subject to world wide copyright protection, and reproduction or imitation in whole or part is expressly forbidden. All reasonable care is taken to ensure accuracy in preparation of the magazine, but Maplin Electronics plc cannot be held legally responsible for its contents. Where errors occur corrections will be published as soon as possible afterwards. Permission to reproduce printed circuit board layouts commercially or marketing of kits must be sought from the publisher.
© Copyright 1990 Maplin Electronics plc.

Bob's MINI-CIRCUITS

From Robert Penfold

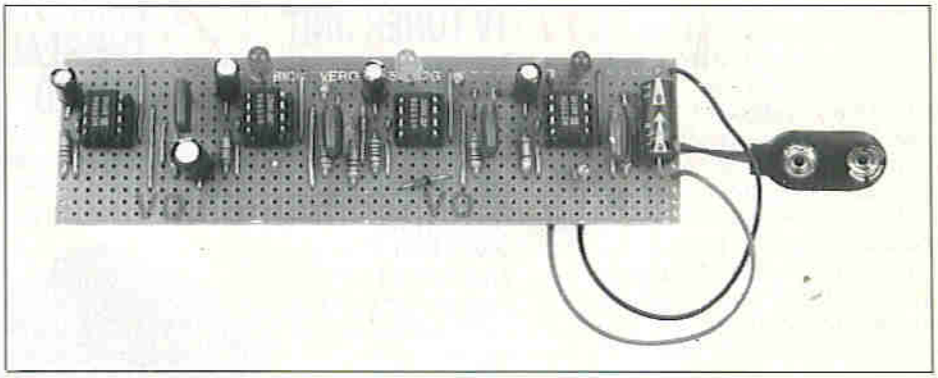
Model Traffic Light

There have been numerous control circuits for model traffic lights published over the years, and virtually all of them are based on logic circuits which comprise a clock oscillator, a decoder circuit, and LED drivers. This design is slightly different, and is based on the ubiquitous 555 timer device (or four of them to be more accurate). They are all operated in the monostable mode, but together act as a useful but little used form of oscillator. This type of oscillator is known as the "ring" type, because the monostables are connected in a ring, with the output of one driving the trigger input of the next. The output from the final monostable is connected back to the input of the first one so as to complete the ring.

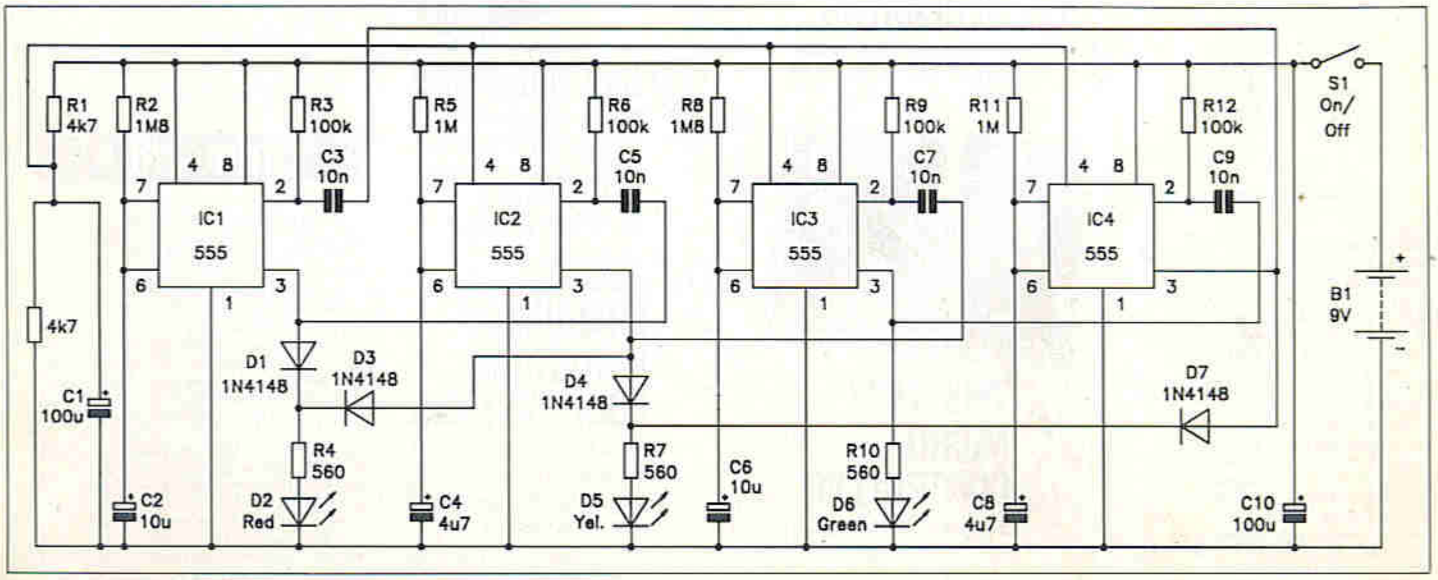
Probably the main reason that ring oscillators are not used a great deal is that they have a reputation for being unreliable. To produce oscillation, initially one of the monostables must be triggered. When its output pulse ceases it triggers the next monostable, which in turn triggers the next one when its output pulse ends, and so on. Due to the feedback from the last monostable to the first, continuous oscillation results, with one monostable at a time producing an output pulse. The reason for the lack of reliability in many ring oscillator designs is that there is no circuitry to ensure that one section, and only one section, is triggered at switch-on.

This circuit uses all four 555's in the standard monostable mode. The trigger inputs are normally held high by 100k resistors, and triggering occurs on the falling edge of the pulse from the previous stage due to the coupling via the 10nF capacitors. At switch-on all the outputs are low, which gives trigger pulses to all the stages. The problem with this particular ring oscillator is therefore one of preventing three stages from triggering rather than having to spur one stage into life. IC1 is allowed to trigger at switch-on, but R1 and C1 provide a negative reset pulse to the other three stages which are therefore held in an inactive state for a short while after switch-on. This gives the d.c. levels in the circuit time to stabilise before these stages become active, and prevents unwanted triggering.

An advantage of this circuit over the more normal digital systems is that the



Traffic Lights.



Circuit for Traffic Lights.

duration of each phase of the simulation is controlled by a separate C – R timing network. The duration of each phase is therefore individually controllable, and can be set at any desired time (within reason). The pulse duration of each monostable is nominally 1.1 C R seconds (with C in microfarads and R in megohms).

A simple diode decoder circuit is used to ensure that each output drives the correct LED or LED's. IC1 controls the "stop" phase, and drives red LED (D2). IC2 provides the next phase, and must therefore drive the yellow LED (D5) as well as the red LED. The next phase is the "green" one, which is controlled by IC3. As this is the only stage that drives the green LED (D6) there is no need for a gate diode to be included here. The final phase is the "yellow" (or "amber") one, and this is governed by IC4. This stage drives the yellow LED via gate diode (D7).

The current consumption of the unit is quite high at about 35mA, and the use of a fairly high capacity battery is recommended. Alternatively, using low power 555's should enable the current consumption to be brought down to only about 10mA (but will significantly increase the cost of the unit).

TRAFFIC LIGHT PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	4k7	1	(M1K)
R2,8	1M8	2	(M1M8)
R3,6,9,12	100k	4	(M100K)
R4,7,10	560Ω	3	(M560R)
R5,11	1M	2	(M1M)
CAPACITORS			
C1	100μF 10V Axial Elect	1	(FB48C)
C2,6	10μF 50V Radial Elect	2	(JL10L)
C3,5,7,9	10nF Polyester	4	(BX70M)
C4,8	4μ7F 63V Radial Elect	2	(FF03D)

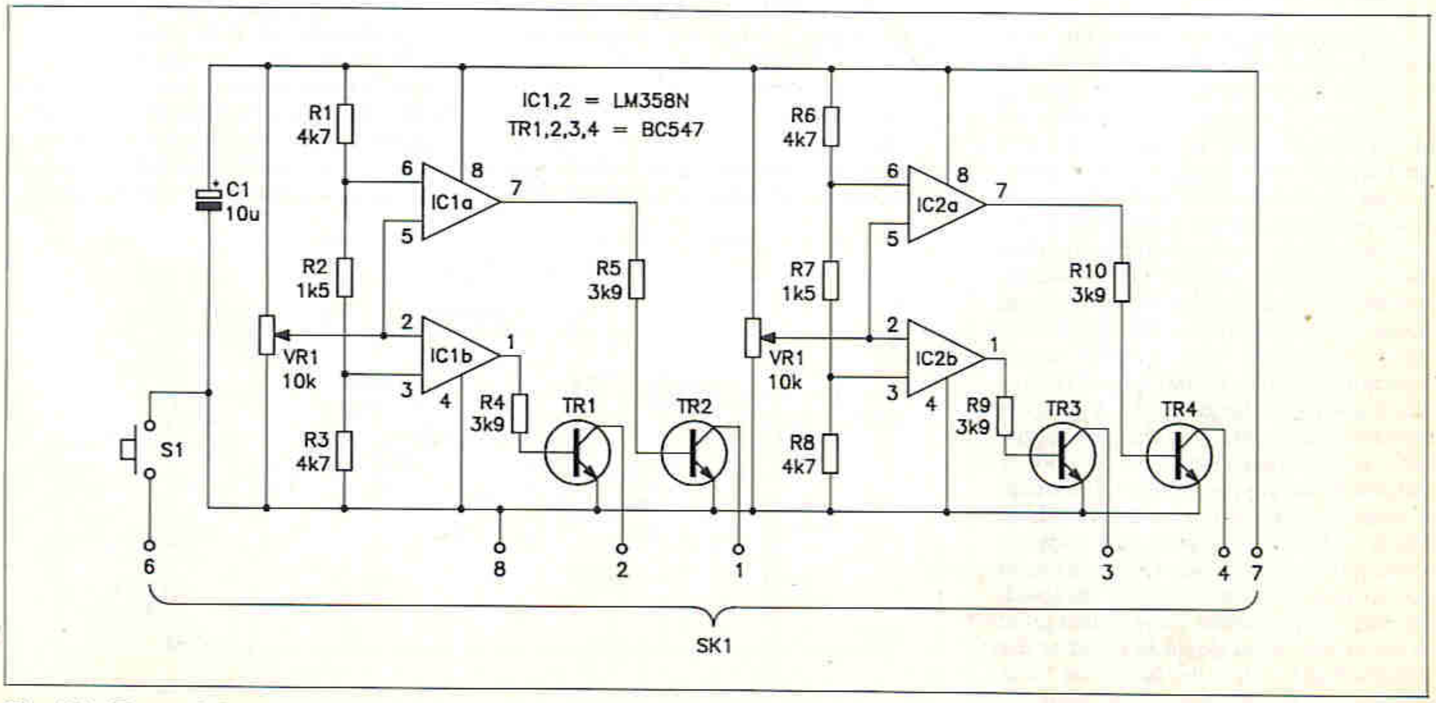
SEMICONDUCTORS			
IC1,2,3,4	NE555	4	(QH66W)
D1,3,4,7	1N4148	4	(QL80B)
D2	5mm Red LED	1	(WL27E)
D5	5mm Yellow LED	1	(WL30H)
D6	5mm Green LED	1	(WL28F)
MISCELLANEOUS			
S1	SPST Ultra-min Toggle	1	(FH97F)
B1	9 Volt (PP9 size)	1	(FM05F)
	Battery Clip	1	(HF27E)
	DIL IC Socket 8-pin	4	(BL17T)

Electronic Joystick

Many popular home computers, including virtually all Atari and Commodore models, use a joystick of the standard switch type having a 9 pin female D connector. This type of joystick is basically just four micro-switches and one push-button type. Moving the stick up, down, left, or right closes a different micro-switch, with intermediate positions closing the appropriate two switches. The push-button switch is, of course, the "firebutton". This arrangement is well suited to many computer games, but it can be a bit awkward with others. For example, racing car simulations often have left and right stick movement for steering, with backwards and forwards movement giving acceleration and braking. With practice you can get used to an arrangement of this type, but it always tends to be something less than completely intuitive.

There have been many attempts at improved joystick designs, and it is not too difficult to devise your own arrangements. It is by no means essential to use any form of stick controller at all. Designs based on five push-button switches, touch switches, and even mercury switches have all been used successfully. This joystick design is intended mainly for use with racing car simulations and similar software which would benefit from have the side to side and up/down controls separated. Control is via two potentiometers, with a rotary type being used for side to side (steering) control, and a slider type providing up/down (acceleration/braking) control.

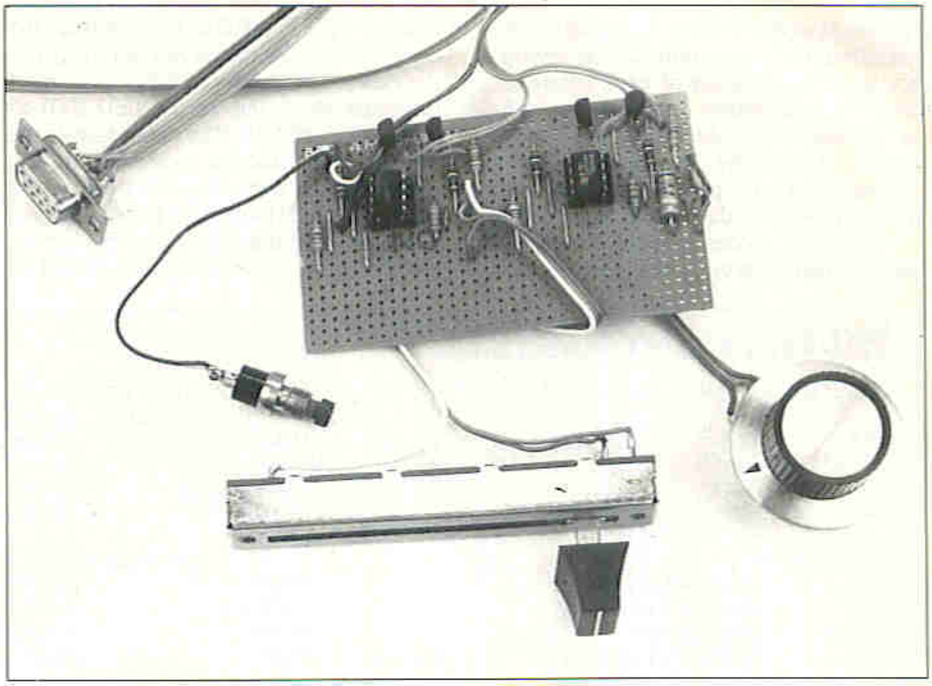
The circuit consists of what are really two identical stages, one for horizontal control and the other for vertical control. If we consider the stage based on IC1, this consists of two operational amplifiers connected as a form of window discriminator. VR1 is the control potentiometer, and it provides the input voltage to the window discriminator. R1 to R3 form a potential divider that sets the upper and lower voltage limits of the window. With VR1 at a central setting, both outputs of IC1 are low. Adjusting VR1 for a substantially higher wiper voltage so that



Circuit for Electronic Joystick.

the upper window voltage is exceeded, results in the output of IC1a going high. TR2 is then switched on, pulling the "up" input (pin 1) of the joystick port low. Adjusting VR1 for a wiper voltage that is below the lower window voltage sends the output of IC1b high, switches on TR2, and activates the "down" input (pin 2) of the joystick port. IC2 operates in an identical circuit that drives the "left" and "right" inputs, while S1 is the push-button switch which drives the "firebutton" input. Power for the unit is obtained from the joystick port, and the current consumption is only a few milliamps.

For any games controller to be a success it is necessary to give careful thought about the placement of the controls. My experiments suggested that results would be best using the two potentiometers on a fairly large panel so that they can be mounted several inches apart. Mount the push-button switch anywhere that puts it within easy reach with one hand or the other. The two potentiometers have a range of central "off" settings, and the width of this range is controlled by the value of R2 and R7. A high value makes the unit difficult to use as the controls then have to be moved through a large rotation range, making it difficult to operate them rapidly. A low value makes it easy to operate the controls rapidly, but they can become excessively fiddly, with it being difficult to locate and leave the controls at the central "off" state. A value of 1.5k is the one I found to be the best compromise, but this value can be altered to suit personal preferences.



Electronic Joystick.

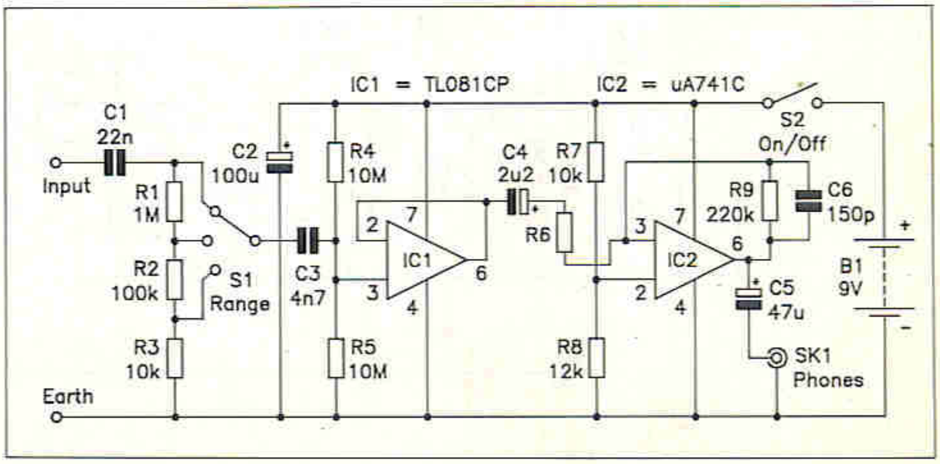
ELECTRONIC JOYSTICK PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,3,6,8	4k7	4	(M4K7)
R2,7	1k5	2	(M1K5)
R4,5,9,10	3k9	4	(M3K9)
VR1	10k Lin Slider	1	(FX33L)
VR2	10k Lin Rotary	1	(FW02C)
CAPACITORS			
C1	10µF 25V Axial Elect	1	(FB22Y)
SEMICONDUCTORS			
IC1,2	LM358N	1	(UJ34M)
TR1,2,3,4	BC547	4	(QQ14Q)
MISCELLANEOUS			
S1	Push to Make – Release to Break	1	(FH91Y)
SK1	9-pin D Socket	1	(RK61R)
	DIL IC Socket 8-pin	2	(BL17T)

Signal Tracer

What probably represents the most useful low cost piece of test equipment for checking linear circuits, apart from a multimeter of course, is some form of signal tracer. This is just a sensitive amplifier driving a loudspeaker or headphones. It can be used to detect the signal at various points in the equipment under test, or perhaps more succinctly, it can be used to detect its absence. The standard method of fault finding using a signal tracer is first to apply an input signal to the faulty equipment (the normal signal source is suitable, or the output from a signal generator can be used). A check is then made about half way along the signal path to determine whether or not a suitable signal is present there. If a signal is detected, then further tests are made at points in the main signal path working towards the output. When a point that does not provide a suitable signal is detected, the fault is somewhere close to that point in the circuit. If no signal is found at the initial test point, then the fault must be at some earlier stage in the circuit. Tests are then made at various points along the main signal path, working towards the input. Again, when an inappropriate signal is detected, the fault is in a component close to that point in the circuit.

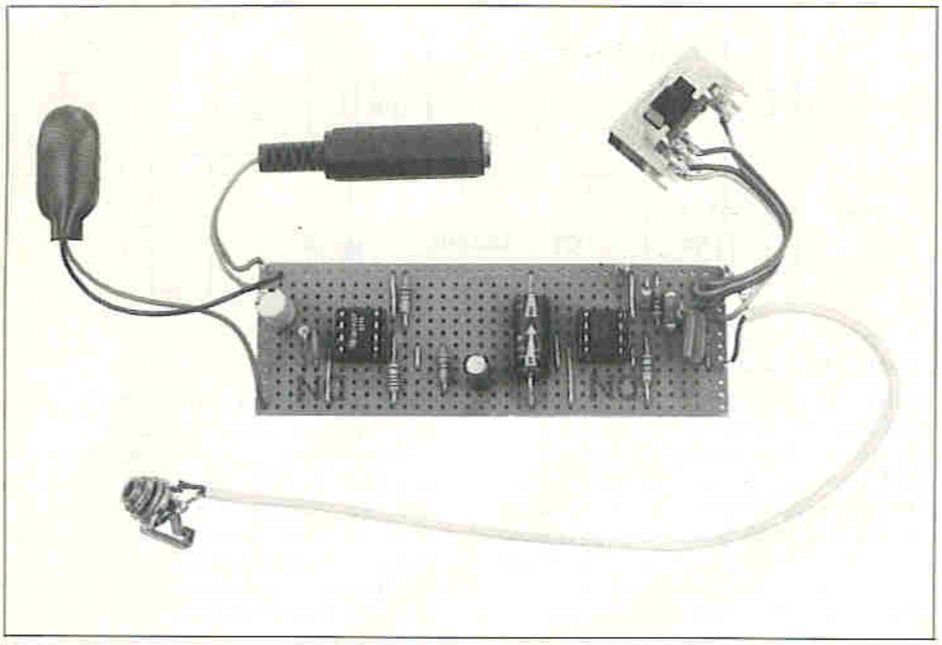
A signal tracer will often fail to pinpoint the exact nature of the fault, and voltage tests etc., using a multimeter, then have to be used to find the exact problem. A signal tracer will at least lead you quite rapidly to the part of the circuit where the fault is located. In some cases it will give a fairly clear indication of which component is faulty. If a signal is present on one side of a coupling capacitor but is absent on the other, then it is reasonably certain that the



Circuit for Signal Tracer.

coupling capacitor is faulty. Sometimes the presence of a signal where there should be none gives a clear indication of the problem. For example, if a signal is found across a decoupling capacitor, it is highly likely that the capacitor is faulty or not connected properly.

This signal tracer circuit has a three step attenuator at the input, providing attenuations of about 0dB, 20dB, and 40dB.



Signal Tracer.

A normal volume control could be used here if preferred, but the unit is designed to be built as a probe type tool. Attenuator switch S1 should be a miniature type, such as a three position slider switch, so that it can be easily fitted into a probe style case, and will be easy to operate. IC1 acts as a buffer stage at the input, and it provides the unit with a suitably high input impedance of about 1 megaohm. IC2 provides the voltage amplification, and this is a standard inverting mode circuit having about 40dB of voltage gain. C6 provides a small amount of high frequency roll-off to aid good stability. The output is intended for use with medium impedance headphones of the type sold as replacements for personal stereos, etc. These should have the 'phones wired in series (i.e. ignore the common earth lead and make the connections to the other two leads).

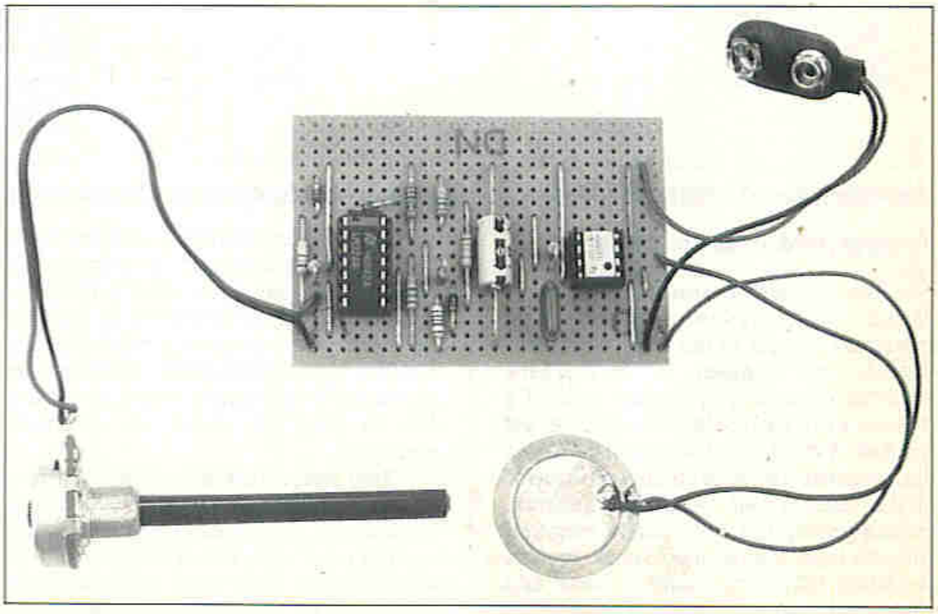
Power is obtained from a PP3 size 9 volt battery. This has an extremely long operating life since the current consumption of the circuit is only about 3mA. In use the unit provides good sensitivity, and will readily detect low level signals such as those from a low impedance microphone. At the other end of the dynamic range it takes signals of several volts peak to peak to overload the unit.

SIGNAL TRACER PARTS LIST

RESISTORS: All 0.6W 1% Metal Oxide			
R1	1M	1	(M1M)
R2	100k	1	(M100K)
R3,7	10k	2	(M10K)
R4,5	10M	1	(M10M)
R6	2k2	1	(M2K2)
R8	12k	1	(M12K)
R9	220k	1	(M220K)
CAPACITORS			
C1	22nF Polyester	1	(BX72P)
C2	100μF 10V Axial Elect	1	(FB48C)
C3	4n7F Polyester	1	(WW26D)
C4	2μ2F 100V PC Elect	1	(FF02C)
C5	47μF 25V PC Elect	1	(FF08J)
C6	150pF Ceramic Plate	1	(WX58N)
SEMICONDUCTORS			
IC1	TL081CP	1	(RA70M)
IC2	μA741C	1	(QL22Y)
MISCELLANEOUS			
S1	3-way Slider	1	(FV02C
S2	SPST Ultra-min Togg.	1	(FH97F)
B1	9 Volt (PP3 size)	1	(FK62S)
SK1	Stereo 3.5mm Jack Socket	1	(FK20W)
	Battery Connector	1	(HF28F)
	DIL IC Socket 8-pin	1	(BL17T)

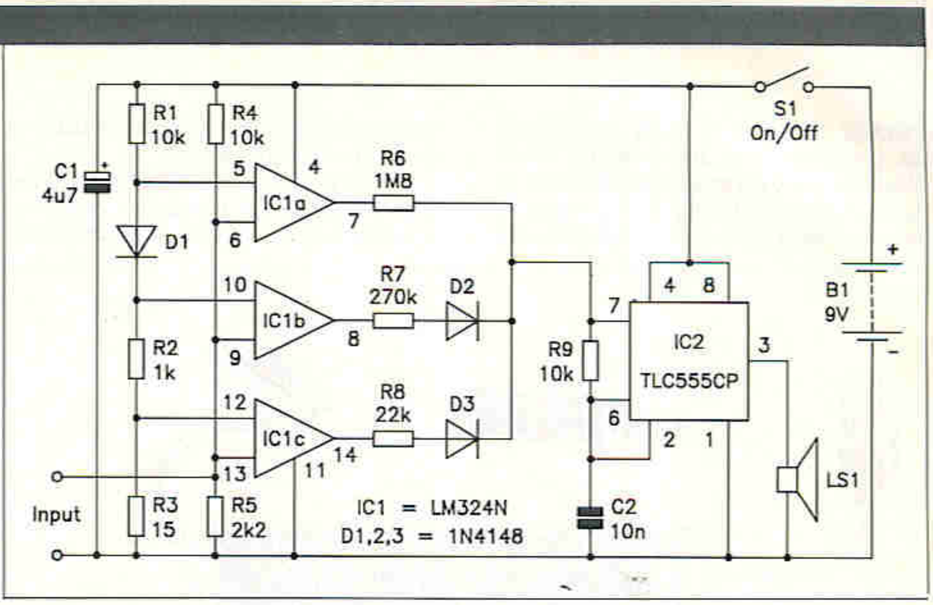
Discriminating Continuity Tester

With printed circuits tending to become ever more complex and intricate, the problem of short circuits between adjacent tracks due to solder blobs and splashes become increasingly acute. Faults due to damaged or missing pieces of track are more rare, but not unknown. The odd break in the tracks is something that can be difficult to avoid if you etch your own printed circuits, with so many contemporary designs calling for very thin tracks. A continuity checker for tracking down short circuits and track breaks is an essential item for any electronic project builder, and a multimeter switched to a medium resistance range will work quite well in this role. It is less than perfect for this type of thing though, and the main criticism is usually that it is rather awkward to keep looking backwards and forwards between the test



Continuity Tester.

prods and the meter.



Circuit for Continuity Tester.

Many "improved" continuity tester circuits have been published, and these usually overcome this problem by using a "beeper" to indicate continuity, rather than some form of visual indicator. Some designs, including this one, have one or two other refinements. Although a multimeter can be a bit awkward to use as a continuity tester, it has the advantage of clearly showing the difference between a true short circuit, a somewhat higher resistance such as a low value resistor or a forward biased semiconductor junction, a higher resistance, and a total lack of electrical conduction. Many continuity tester circuits give little idea of the resistance between the test points, and often indicate continuity when there is a low but significant resistance across the test prods. Some are even activated if they are connected across a forward biased semiconductor junction.

This continuity tester circuit was designed to be built as a probe type tool, but could be built as a conventional unit if preferred. It has the ability to differentiate between a very low resistance, a higher but still quite low resistance or a forward biased junction, a higher resistance of several kilohms, and a very high resistance. These are indicated by a high pitched "beep", a medium pitched "beep", a low pitched "buzz", and no output (respectively). This gives more information than the simple dual state indication of most continuity testers, but does not require the user to look away from the test points.

The circuit is based on three operational amplifiers (IC1) which are used here as voltage comparators. Note that the LM324N used for IC1 is actually a quad device, but in this circuit one amplifier is left unused. The non-inverting inputs are fed with different voltages from a potential divider circuit, while the inverting inputs are all fed with the same voltage which comes from a second divider circuit. This last voltage is the highest one, and it results in all three outputs going low. This mutes the audio oscillator based on IC2 (which is a low power 555 timer in the standard astable mode). Placing a decreasing resistance across the input of the unit results in the voltage to the inverting inputs decreasing. As it goes below the reference voltages at the non-inverting inputs, first IC1a's output goes high, then that of IC1b, and finally the output of IC1c goes high. As each output goes high, it places a lower timing resistance in circuit, and boosts the output frequency of IC2. This gives the three tones to indicate the three levels of continuity. The three pitches are well separated so that they are easily distinguished from one another even if you do not have a very good sense of pitch.

The current consumption of the unit is quite low at about 2.5mA to 3.5mA. An ordinary PP3 size battery is perfectly adequate as the power source. Note that LS1 is not a moving coil loudspeaker, but is a ceramic resonator. An uncased type mounted behind a cutout or grille in the case should be suitable. It will only give a low volume output, but for an application of this type a higher volume is undesirable.

DISCRIMINATING CONTINUITY TESTER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,4,9	10k	3	(M10K)
R2	1k	1	(M1K)
R3	15Ω	1	(M15R)
R5	2k2	1	(M2K2)
R6	1M8	1	(M1M8)
R7	270k	1	(M270K)
R8	22k	1	(M22K)
CAPACITORS			
C1	4µ7F 100V Axial	1	(FB18U)
C2	10nF Polyester	1	(BX70M)
SEMICONDUCTORS			
IC1	LM324N	1	(UF26D)
IC2	TLC555CP	1	(RA76H)
D1,2,3	1N4148	3	(QL80B)
MISCELLANEOUS			
S1	SPST Ultra-min Toggle	1	(FH97F)
LS1	27mm Piezo Transducer	1	(QY13P)
B1	9 Volt (PP3 size)	1	(FK62S)
	Battery Connector	1	(HF28F)
	DIL IC Socket 8-pin	1	(BL17T)
	DIL IC Socket 14-pin	1	(BL18U)

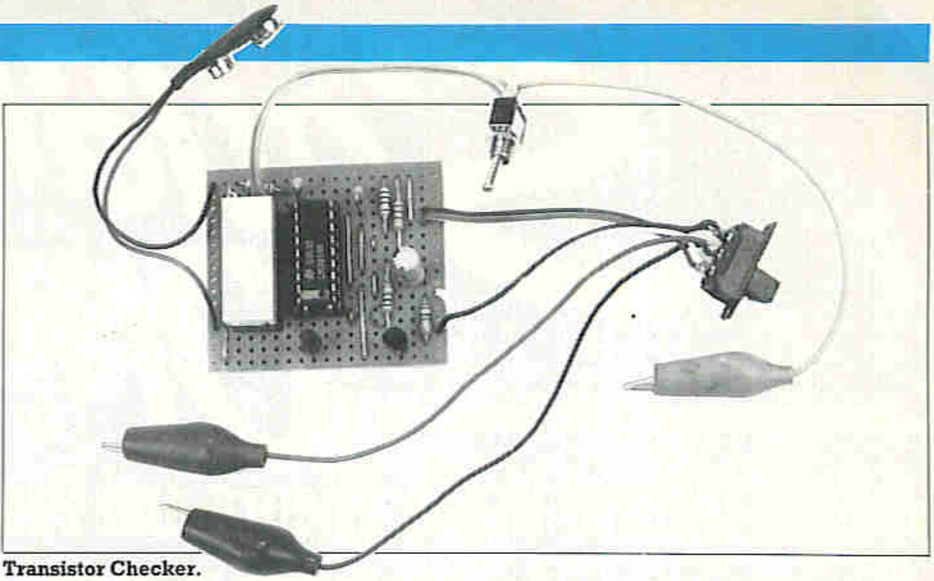
Transistor Checker

The traditional transistor checker design has a resistor to provide a reference current to the base of the test device, and a meter to monitor the collector current. The current gain of a transistor is equal to the collector current divided by the base current, and therefore the meter can easily be calibrated in terms of d.c. current gain. As highly accurate measurements are not usually required with this type of equipment (most devices are either fully serviceable or "dud" and very low in gain), a low cost "tuning" or "level" meter is often used as the basis of these units. This transistor checker uses the alternative approach of a bargraph display. This may seem a bit gimmicky, but it is a practical approach in that this type of display is physically much tougher than any moving coil panel meter. There is no real risk of damage to the meter section due to physical shock or electrical overloads.

Two ranges are provided, with one having a full scale value of 100 and a resolution of 10, and the other having a full scale value of 1000 and a resolution of 100. This enables both high and low gain devices to be checked with reasonable accuracy. The circuit is based on the ever popular LM3914N bargraph display driver. This can be used in the "bar" or "dot" mode, and in this case it operates in the true bargraph mode. This gives a clearer display than the "dot" mode, but at the expense of a significantly higher current consumption. The internal voltage reference is used, and this sets the full scale sensitivity at 1.2 volts. In this case it is a current meter that is required rather than a voltmeter. R7 is connected across the input, and effectively converts the display circuit to a current meter having a full scale value of 10mA. R6 helps to keep the current flow down to an acceptable level if the test device is closed circuit. D1 to D10 are the bargraph LED's, and on the prototype these are a proper bargraph component. However, ten ordinary panel LED's could be used here if preferred. R8 controls the LED current, and sets it at about 6mA. The use of a reasonably efficient display of LED's is recommended.

Reference currents of about 10μA and 100μA are provided at the base of the test device by R3 or R4, with the desired resistor being selected using range switch S1. By taking this bias current from a mid-supply tapping, the need for NPN/PNP switching in the base circuit is avoided. Initially, test the device with the base unconnected so as to ensure that it has insignificant leakage (i.e. no LED's should switch on). Alternatively, add a switch in the base lead so that base current can be switched off to check the leakage level, and turned on for current gain measurement.

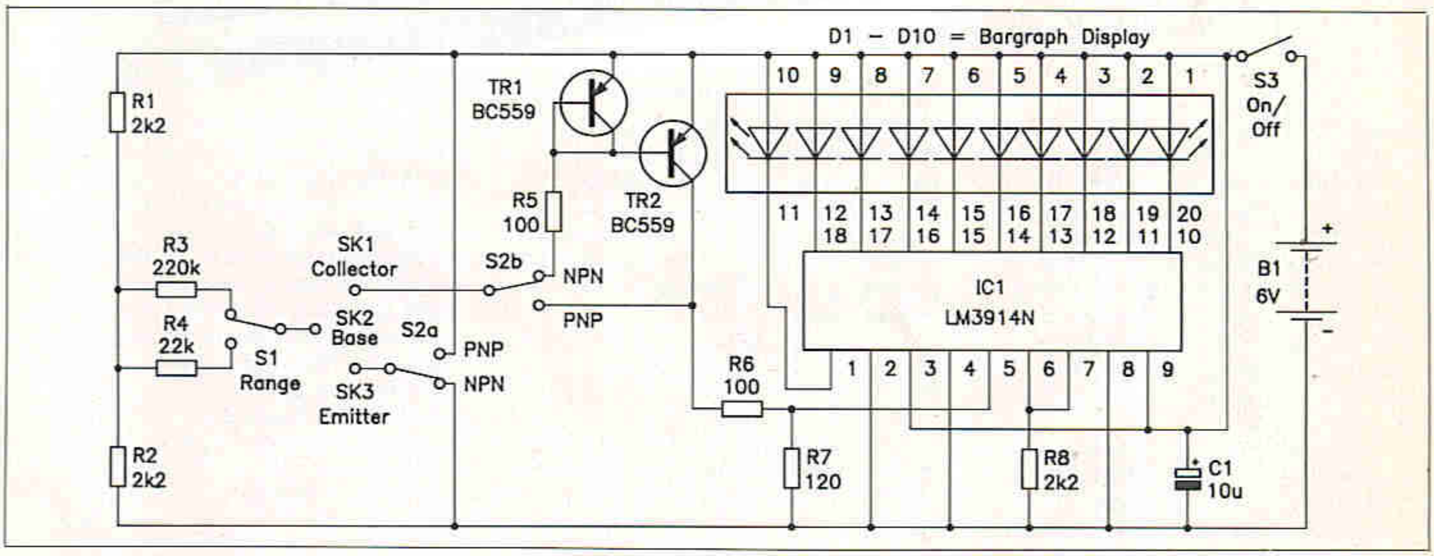
S2a provides NPN/PNP switching in the emitter circuit, while S2b performs the same function in the collector circuit. There is a slight problem in that an NPN test component will sink its collector current, whereas the meter circuit requires a current source. To overcome this problem a current mirror comprised of TR1 and TR2 is used to effectively convert NPN test devices to current sources. R5 protects the current mirror against excessive input currents.



Transistor Checker.

The finished transistor checker requires no calibration, and is ready for immediate use. The current consumption is largely dependent on the number of LED's that are switched on. The quiescent consumption is about 7mA, but the supply current can be close to 100mA with all ten LED's activated. Four HP7 size cells in a plastic holder make a good power source for the unit, and will give many hours of use despite the relatively high current drain.

When using any simple transistor tester you need to bear in mind that current gain ranges in data sheets are quoted at specific collector currents and voltages. With this tester the collector voltage is anything from little more than zero to about 6 volts, and the collector current is anything from zero to approximately ten milliamps. What this means in practice is that a test device which measures as being just outside the acceptable gain range is probably perfectly serviceable. The discrepancy is probably due to the wrong collector current/voltage being used, or a slight lack of accuracy due to the component tolerances of the tester itself. In the case of power transistors, the indicated gain will often be somewhat lower than the data sheet would suggest. This is simply because power devices normally have their gain figures quoted at quite high currents, but a simple tester of this type can only use a moderate test current. Fortunately, most "duds" are quite easy to spot – they are usually either open circuit or closed circuit.



Circuit for Transistor Checker.

TRANSISTOR CHECKER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,2	2k2	2	(M2K2)
R3	220k	1	(M220K)
R4	22k	1	(M22K)
R5,6	100Ω	2	(M100R)
R7	120Ω	1	(M120R)

CAPACITORS

C1	10μF 50V PC Elect	1	(FF04E)

SEMICONDUCTORS

IC1	LM3914N	1	(WQ41U)
TR1,2	BC559	2	(QQ18U)
D1-D10	Red 10 Seg. Bargraph Display	1	(BY65V)

MISCELLANEOUS

S1	SPDT Ultra-min Toggle	1	(FH98G)
S2	DPDT Slider	1	(FH36P)
S3	SPST Ultra-min Toggle	1	(FH97F)
B1	6 Volt (4 x HP7 size)	4	(FK55K)
SK1,2,3	Transistor Socket	1	(WR29G)
	Battery Holder (4 x AA)	1	(HF29G)
	Battery Connector	1	(HF28F)
	DIL IC Socket 18-pin	1	(HQ76H)
	DIL IC Socket 20-pin	1	(HQ77J)

Square One

A First Course in the Theory and Practice of Electronics

Part 3 by Graham Dixey C.Eng., M.I.E.E.

Resistance, Reactance and Impedance

Figure 1 shows three passive components, a resistor, a capacitor and an inductor (coil). Each of these is able to oppose the flow of current through them, but it depends upon whether the current is direct or alternating and, if the latter two, what the frequency is.

Taking the resistor first of all, we say that this component has the property of 'resistance', denoted by R and measured in ohms (Ω). Except for special cases, resistance is generally assumed to be the same whether the current is d.c. or a.c.

That is, if R = 1000 ohms and V = 10V, then I = V / R
= 10 / 1000
= 0·01A
whether V is d.c. or a.c.
(I = V / R is Ohm's Law).

Now taking the case of a capacitor, because this consists of two metal plates separated by an insulator (the dielectric), no direct current flows through it at all; we say that the capacitor has a 'blocking' action for d.c. There is an initial flow of current, a short surge, when the direct voltage is first applied, but this merely stores static energy within the capacitor (see Appendix).

The situation is quite different for a.c. The plates are made alternately positive and negative by the alternating nature of the applied voltage. First a charging current flows in one direction, then in the other as the a.c. reverses. It appears that there is a current flowing backwards and forwards through the capacitor, that is itself alternating. The value of this current depends, not merely on the amplitude of the applied voltage, but also on its frequency; it also depends upon the value of capacitance (capacitance is the property of a capacitor). There is an 'Ohm's law' type of relationship as follows:

$I = V / X_C$
$a = I \times X_C$
$X_C = V / I$

where $X_C = 1 / (2 \times \pi \times f \times C)$ and is known as the 'capacitance reactance'.

Photo 1. Suggested front panel layout for the power supply unit.

Notice that X_C is 'inversely' proportional to frequency, so that the higher the frequency, the lower the capacitive reactance. Reactance is measured in ohms, not surprisingly.

Example. A capacitor of value 100nF, at a frequency of 400Hz, will have a reactance of:

(Note: $100nF = 100 \times 10^{-9}F$)
$X_C = 1 / (2 \times \pi \times 400 \times 100 \times 10^{-9})$
= 3979 ohms

The same capacitor would have a reactance equal to only 1/10 of this value at 4000Hz (397·9 ohms), but 10 times this value at 40Hz (39·79 ohms).

Finally, consider the case of a coil (inductor). This is somewhat more complicated because practical coils, being wound from many turns of copper wire, will have a d.c. resistance as well as offering an opposition to a.c. However, sometimes, the coil resistance is quite small and can be neglected. For the moment we will assume that that is the case. Note though that whatever the value of resistance, this is the only opposition that the coil offers to d.c. It is more useful now to consider what opposition the coil offers to a.c.

Current flowing in a coil produces a magnetic field within the coil. This field

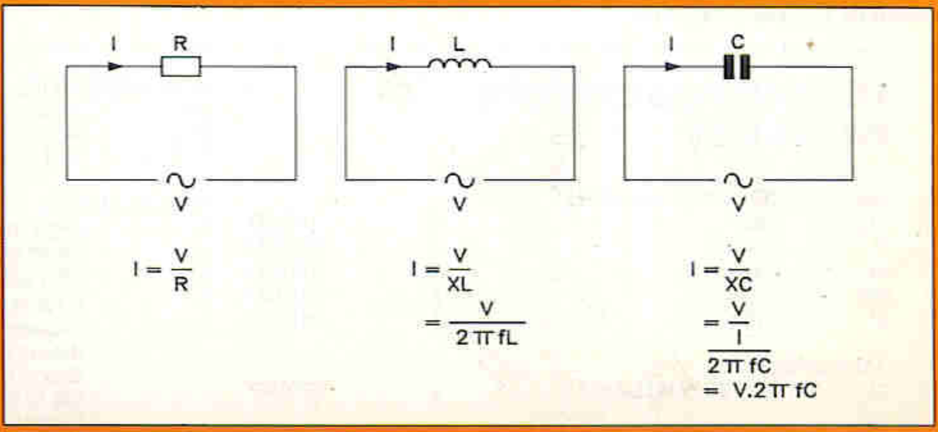


Figure 1. A resistor, capacitor and inductor all oppose the flow of current but in different ways.

represents stored energy (see Appendix). Every time the current reverses, the field (and hence the energy in the field) has to be re-established in the opposite direction. There is a natural reaction to this reversal, which is covered by what is known as Lenz's Law (see Appendix). This is, in effect, the opposition that the coil offers to a.c., and it is known as 'inductive reactance'. The value of this reactance is expressed by:

Inductive reactance, $X_L = 2 \times \pi \times f \times L$ ohms.

Notice from this, that inductive reactance is 'directly' proportional to frequency.

Example. A coil of inductance (the property of an inductor) 200mH, at a frequency of 500Hz, has a reactance of:

(Note: 200mH = 0.2H)
$X_L = 2 \times \pi \times 500 \times 0.2$
$= 628{\cdot}3$ ohms

At a frequency 10 times higher, that is 5000Hz, the reactance will be 10 times greater, that is 6283 ohms, while at 50Hz it will be only 62·83 ohms.

So what is 'impedance'? The answer is simple; it is a combination of resistance and reactance and is, of course, measured in ohms. The symbol for impedance is Z. It is calculated from the expression:

$Z = \sqrt{(R^2 + X^2)}$

It applies equally to combinations of resistance with either type of reactance, capacitive or inductive. For example, if a circuit consisted of 20 ohms resistance in series with 30 ohms reactance but is less than would be obtained by a plain arithmetic sum, which would, in this case, give an answer of 50 ohms.

Phase Angle, Phasors and Phasor Diagrams

The sinewave should by now be quite familiar. If a sinewave of voltage at any frequency you like is applied to a resistor, then a sinewave of current, at the same frequency, will flow through the resistor. If the two sinewaves of voltage and current can be viewed together (by using a double-beam C.R.O.) they will be seen to rise and fall exactly together. They are said to be IN PHASE. See Figure 2(a).

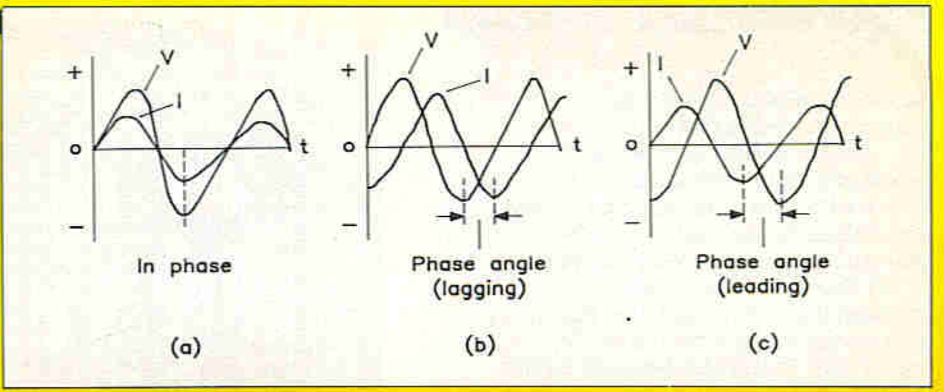


Figure 2. Phase relationship between applied voltage and current for (a) a resistor, (b) a coil and (c) a capacitor.

Now if the sinewaves of voltage and current in either a capacitor or a coil are viewed in a similar way, they will, of course, have the same frequency but will not rise and fall exactly together. They are said to be OUT OF PHASE. The sinewave that reaches its maximum value first is said to LEAD the other, while the one that is behind is said to LAG on the other.

In the specific case of a coil (assumed for the moment to have negligible d.c. resistance), it is the current LAGS the voltage. In the case of a capacitor, the opposite is true: the current LEADS the voltage. See Figures 2(b) and 2(c). The difference between the two waveforms, measured horizontally, is known as the 'phase angle'. For the cases of Figures 2(b) and 2(c), this difference is exactly a quarter of a cycle, corresponding to an angle of 90°.

There is an easy way of remembering which lags or leads on the other as follows: All that is necessary to do is remember the simple word CIVIL, in which the C is assumed to mean capacitance, the L is for inductance. Naturally, I and V mean current and voltage respectively. From this it can be seen that for C, I LEADS V, while for L, I LAGS V.

A 'phasor' is a line that has both 'magnitude' and 'direction'. It is common to make a 'reference phasor' point horizontally to the right. This reference may be either a voltage or a current. Other quantities are then drawn of the appropriate length and at relative angles to it.

Figure 3 shows several phasor diagrams, each with corresponding circuit to which it applies.

(a) shows resistance only; V and I are in phase.
(b) shows capacitance only; I leads V by 90°.
(c) shows inductance only; I lags on V by 90°.
(d) shows C and R is series; I leads V by less than 90°. The two voltage phasors, V_R and V_C, form a 'triangle of voltage' of which the hypotenuse is the applied voltage V.
(e) shows a similar diagram to (d) for L and R in series, but now I lags V by less than 90°.

There are as many different phasor diagrams as there are possible combinations of L, C and R. Some of them are very complex but they all follow the ideas of 3(a) to (e).

More on Amplifiers

We know from the last article, that the purpose of an amplifier is to increase the magnitude of, or amplify, the input signal. This is expressed by the 'gain', which is the ratio output/input. This may be given as a simple ratio or be expressed in decibels (dB). Amplifiers may have other characteristics, which

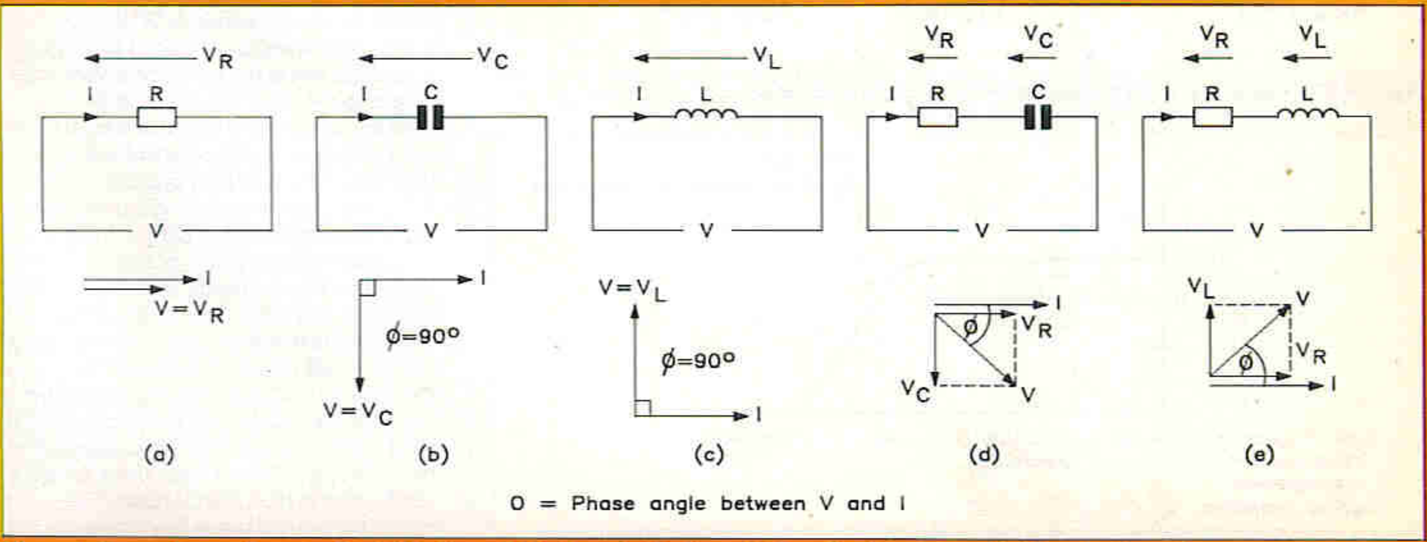


Figure 3. Some phasor diagrams for (a) R alone, (b) C alone, (c) L alone, (d) C and R in series and (e) L and R in series.

may sometimes have particular importance. Among these are:

1) Input impedance: more often considered as just resistance, this is measured between the input terminals of the amplifier for a.c. signals only. In general, the higher its value, the better.

2) Output impedance: also considered as a resistance, this appears between the output terminals for a.c. signals only. It is usually desirable for this to be as small as possible.

Figure 4 illustrates the above ideas, and can also be used to explain their practical significance.

A source of voltage V_S (of amplitude 100mV RMS) has its own internal resistance (as all practical sources do), in this case, R_S = 600 ohms. The input impedance, R_{IN}, of the amplifier appears to the signal as a 2000 ohm resistance. The output of the amplifier is a voltage, V_O, (the signal voltage produced by amplification of the input) in series with the output impedance of the amplifier, which is a resistance, R_O, of value 500 ohms. A resistive load of 2500 ohms is connected across the output. The gain of the amplifier is 50. The question is, 'what is the output voltage'?

It might be thought that, since output = gain x input, that the answer would simply be equal to 40 x 0·1V = 4V. (100mV = 0·1V). This is certainly not the case, as can be shown.

For a start, the actual input to the amplifier isn't 100mV at all. This is merely what the signal source (playback head, microphone, radio tuner, etc.) develops. This voltage is divided between R_S and R_{IN} in direct proportion to their values.

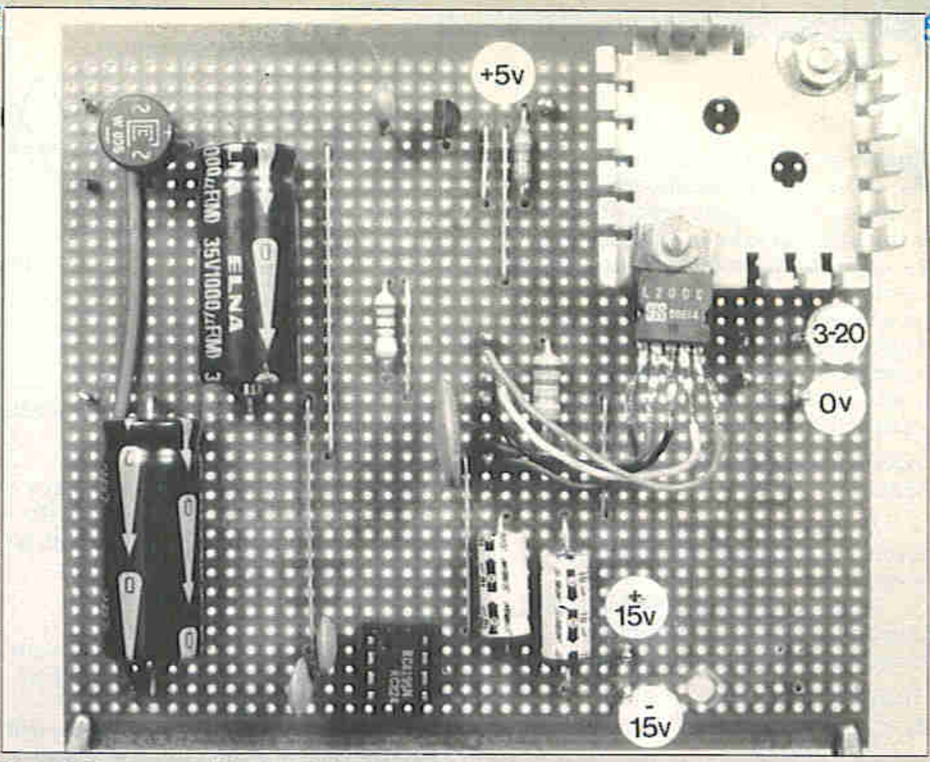


Photo 2. Component side view of circuit board. The heatsink used for IC3 need only be a plain aluminium tab; the elaborate one shown here was just conveniently to hand.

This implies that some of the available signal is 'lost' across R_S. This immediately makes it clear why R_{IN} should be as large as possible, since the larger it is, the greater will be the proportion of the signal appearing across it. The actual value for the circuit shown is calculated as follows:

Voltage appearing across $R_{IN} = V_S$ x $R_{IN} / (R_S + R_{IN})$
= 0·1 x 2000 / (600 x 2000)
= 0·1 x 0·77
= 0·077V (77mV)

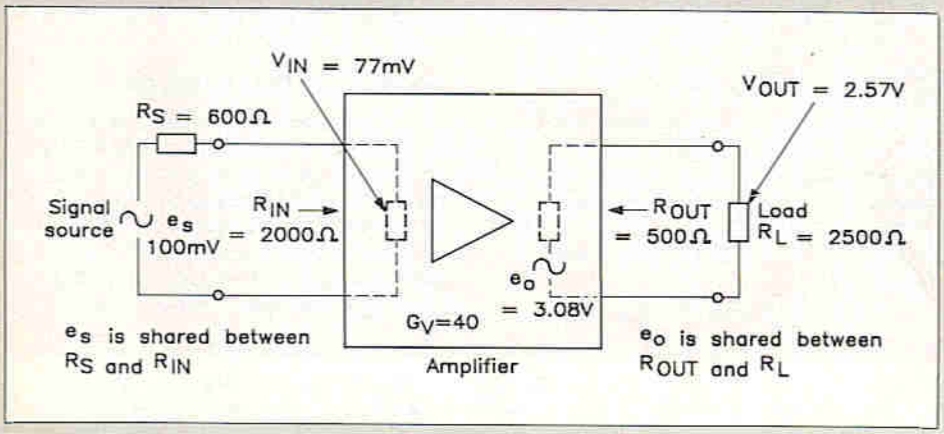


Figure 4. The meaning of input and output impedance of an amplifier.

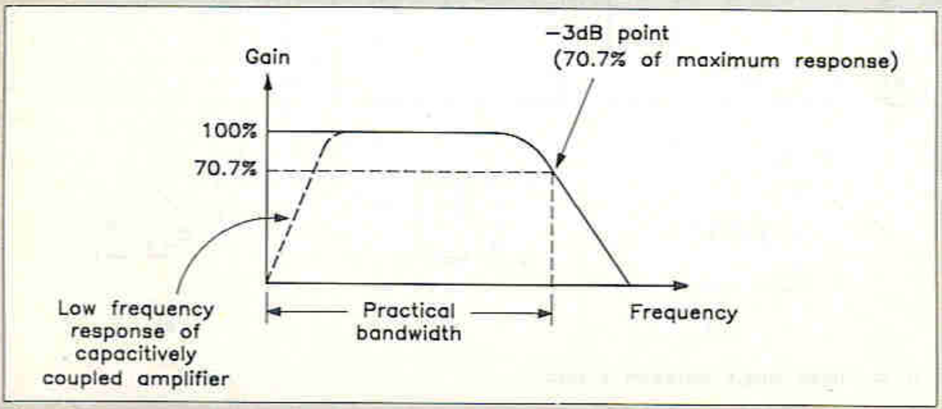


Figure 5. The meaning of input and output impedance of an amplifier.

It is this value of voltage that is amplified 40 times to give an output of 40 x 0·077, = 3·08V.

Even this is not the output that appears across the 2500 ohms load, R_L because part of it is dropped across the output impedance, R_O. The actual voltage across R_L is obtained by the same method as was used to calculate the true input voltage. Obviously, the smaller the value of R_O, the larger will be the proportion of available voltage obtained.

That is, output voltage across R_L
= 3·08 x 2500/(500 + 2500)
= 3·08 x 2500/3000
= 2·57V

This is well short of the 4V output that might have been otherwise assumed.

3) Bandwidth: the gain of an amplifier is never absolutely constant with frequency, though it is possible to design it so that it is reasonably so over a particular range of frequencies, for any given application. For example, the normally accepted range of audio frequencies for good quality reproduction of music is usually considered to lie between 20Hz and 20kHz. Bandwidth is a method for stating in specific terms the range of frequencies for which the gain is more or less constant within certain limits. These limits are termed the −3dB points of response, which are illustrated in Figure 5.

Just to jog the memory, a reduction of −3dB corresponds to a fall from some maximum value to 70·7% of this maximum. For example, if the maximum gain of an amplifier is 100 then, at the −3dB points the gain is 70·7. There 'may' be two −3dB points on the response characteristic of an amplifier, one at low frequencies, one at high frequencies. The word 'may' is emphasised because in the case of many IC amplifiers, there is only a −3dB point at high frequencies. The curves for both of these two cases are included in Figure 5.

Field Effect Transistors (FETs)

These devices fall into two main classes – IGFETs (Insulated Gate FETs) and JUGFETs (JUnction Gate FETs). It is the latter type that we shall consider here. Known generally simply as FETs, these transistors are significantly different in principle and application from Bipolar Junction Transistors (BJTs). They are, of course, active devices and are, therefore, capable of amplifying signals. A simple form of FET amplifier is shown in Figure 6.

This figure also shows the circuit symbols for the two types, known as N-channel and P-channel. As with NPN and PNP bipolar transistors, the main difference is in the polarity of the supply. The latter, known as V_{DD}, is positive for N-channel devices and negative in the case of P-channel types. The three electrodes are termed the DRAIN (D), GATE (G) and SOURCE (S), corresponding more or less with the collector, base and emitter, respectively, of the bipolar transistor.

The voltages and currents of importance are shown in Figure 6 (b) and the situation will be seen to be somewhat simpler than for the BJT. There are just two voltages and two currents. This simplifies even further when it is realised that the two currents are really one and the same; it is just given a different name, I_D or I_S, according to which terminal it enters or leaves. This is because there is no gate current. Therefore, whatever current enters the source terminal will flow through the FET and leave at the drain terminal. The two voltages shown are V_{DS}, the drain-source voltage and V_{GS}, the gate-source voltage, which has a particular importance. A voltage, V_{DG}, does, of course, exist between drain and gate, but is rarely of interest in considering circuit operation.

For any type of transistor to operate satisfactorily as an amplifier, it must be 'biased'. This means that the correct value of current is set up in the transistor. In the case of a BJT, it is done by making a particular value of current flow in the base lead. In the case of a FET, it is carried out by setting up a 'bias voltage' between the gate and source terminals. For any given value of this voltage, V_{GS}, there is a corresponding value of drain current, I_D. This relationship can be seen in the 'transfer characteristics' of Figure 7.

The transfer characteristic is a graph of current I_D against voltage $-V_{GS}$. Note the minus sign. If a particular drain current is required, all that it is necessary to do is to project this value across to the curve and down to the horizontal axis to read off the corresponding value of $-V_{GS}$. An example is shown in Figure 7. It might seem from this that there is a negative voltage in the circuit. Well, there isn't as such. What $-V_{GS}$ means is that the gate is negative 'relative to the source'. Put another way, the source is 'positive with respect to the gate'. This is easy to achieve in practice. Back to the circuit of Figure 6.

The gate is connected to the 0V line through the resistor R_G; we say it is 'referred to 0V', meaning that, as far as

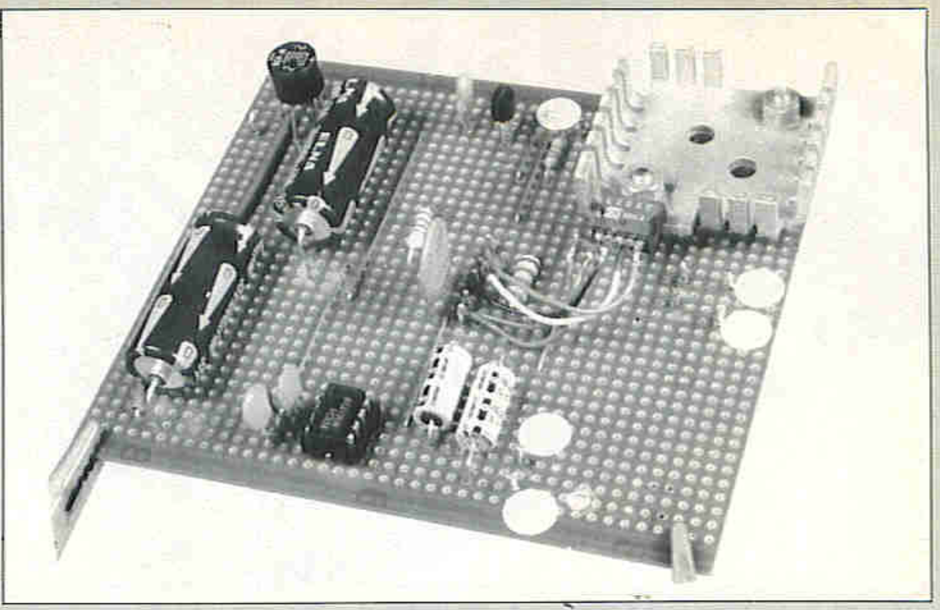


Photo 4. Oblique view of assembled board.

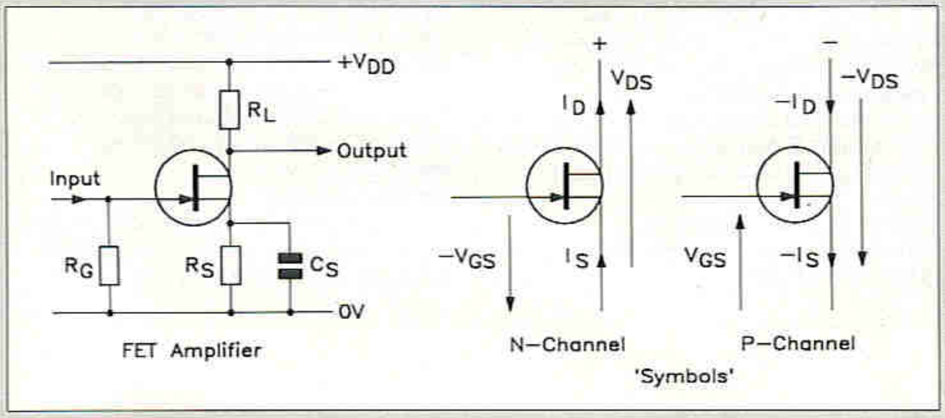


Figure 6. A simple amplifier using a junction-gate FET.

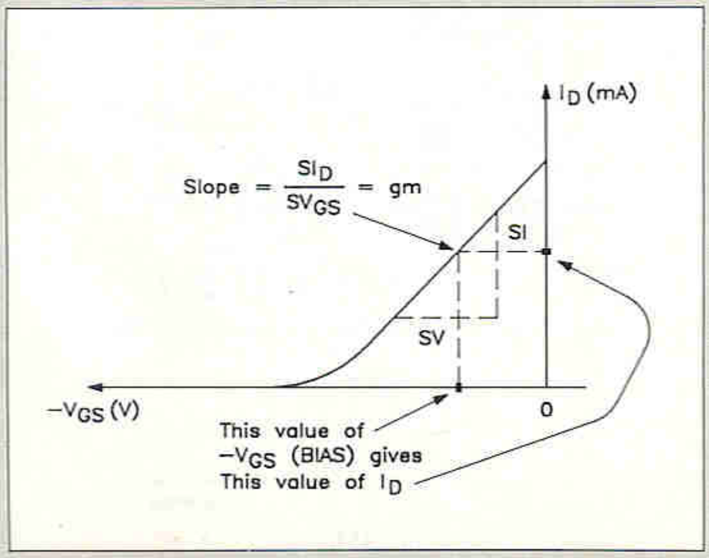


Figure 7. The transfer characteristic of a FET; this shows the relation between gate bias voltage and drain current.

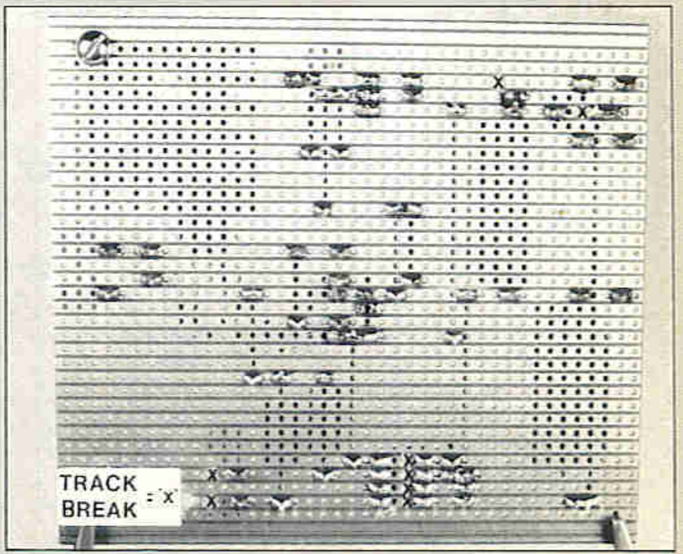


Photo 3. Copper side view of circuit board. Note carefully the track breaks required: there are just eight of them.

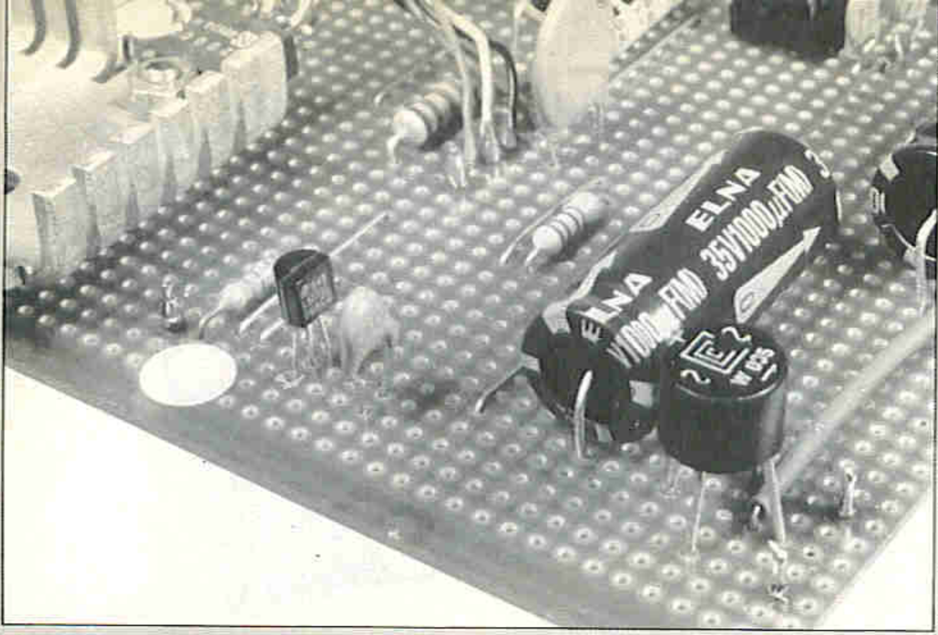


Photo 5. Close-up of the bridge rectifier and +5V section.

d.c. is concerned, the gate is at zero volts. Now look at the source. This goes to 0V through a resistor R_S and, because the source current I_S flows through this resistor, the source is 'positive with respect to 0V' (and hence also positive with respect to the gate) by a voltage equal to $I_S \times R_S$. For the latter current we could justifiably substitute I_D instead, since I_S and I_D are numerically equal. For practical purposes, therefore, the volt drop across R_S equals $I_D \times R_S$. Whichever way we look at it, the object of making the gate effectively negative with respect to source, by the required amount, has been achieved.

It is easy to calculate the value of R_S once the value of I_D and $-V_{GS}$ have been obtained from the transfer characteristic. Suppose that for a drain current of 2mA the value of $-3{\cdot}6V$ is read off the $-V_{GS}$ scale. By Ohm's law, the value of $R_S - V_{GS}/I_D$, which equals 3·6V/2mA or 1·8K.

The transfer characteristic has another useful function. The slope of this curve is 'change of I_D/change of V_{GS}', which is variously called the 'forward transconductance' (symbol g_{fs}) or 'mutual conductance' (symbol g_m). We shall use the latter. If we divide current by voltage, which is what we have done here, we get 'conductance' (clearly the reciprocal of resistance). The unit for conductance was once the 'mho' (ohm written backwards!); nowadays it is the Siemen (symbol S). If we divide milliamps by volts (as we usually do in a practical situation), we get milli-Siemens (mS). Note that 'capital S' and avoid confusion with ms, which means milli-seconds, quite a different unit altogether.

This quantity is called 'mutual' because it is a ratio of an 'output' quantity over an 'input' quantity. That gives us a clue as to its usefulness, when we remember that the gain of an amplifier is output/input. In fact, g_m is used to give the voltage gain of a FET amplifier by the simple relation:

Voltage gain $A_V = -g_m \times R_D$

(where R_D is the value of the load resistor in the drain circuit).

The minus sign in the above expression means that there is a phase shift of 180° between the input and output of the amplifier. It is a commonly used mathematical convenience that shouldn't be allowed to confuse anyone.

At this point it is worth returning to the matter of input impedance. One of the advantages of the FET is its very high value of this quantity. Whereas a similar amplifier using a BJT might well have an input impedance of only 2 – 3 kilohms, the figure for a FET would be as many Megohms. A FET amplifier can make a useful first stage in many applications, since its high input impedance will not 'load' the signal source. Two application circuits are shown in Figure 8. Circuit (a) shows a simple electronic voltmeter with very high input impedance; circuit (b) shows the first stage of an amplifier used for disk reproduction. This amplifier has a particular frequency response known as a RIAA 'equalising characteristic' (RIAA = Radio Industry Association of America). The gain of the amplifier is a maximum at low frequencies and then falls with increasing frequency, a type of response which is required with magnetic pick-ups.

Instruments for Measuring Amplifier Performance

There are three instruments of particular value in measuring the performance of amplifiers (and other circuits, of course). These are, the signal generator (SG), the electronic voltmeter (EVM) and the cathode ray oscilloscope (CRO). A brief resumé of their main features is as follows:

Signal Generator

Instruments of this type are available for generating test signals anywhere in the audio and radio frequency spectra.

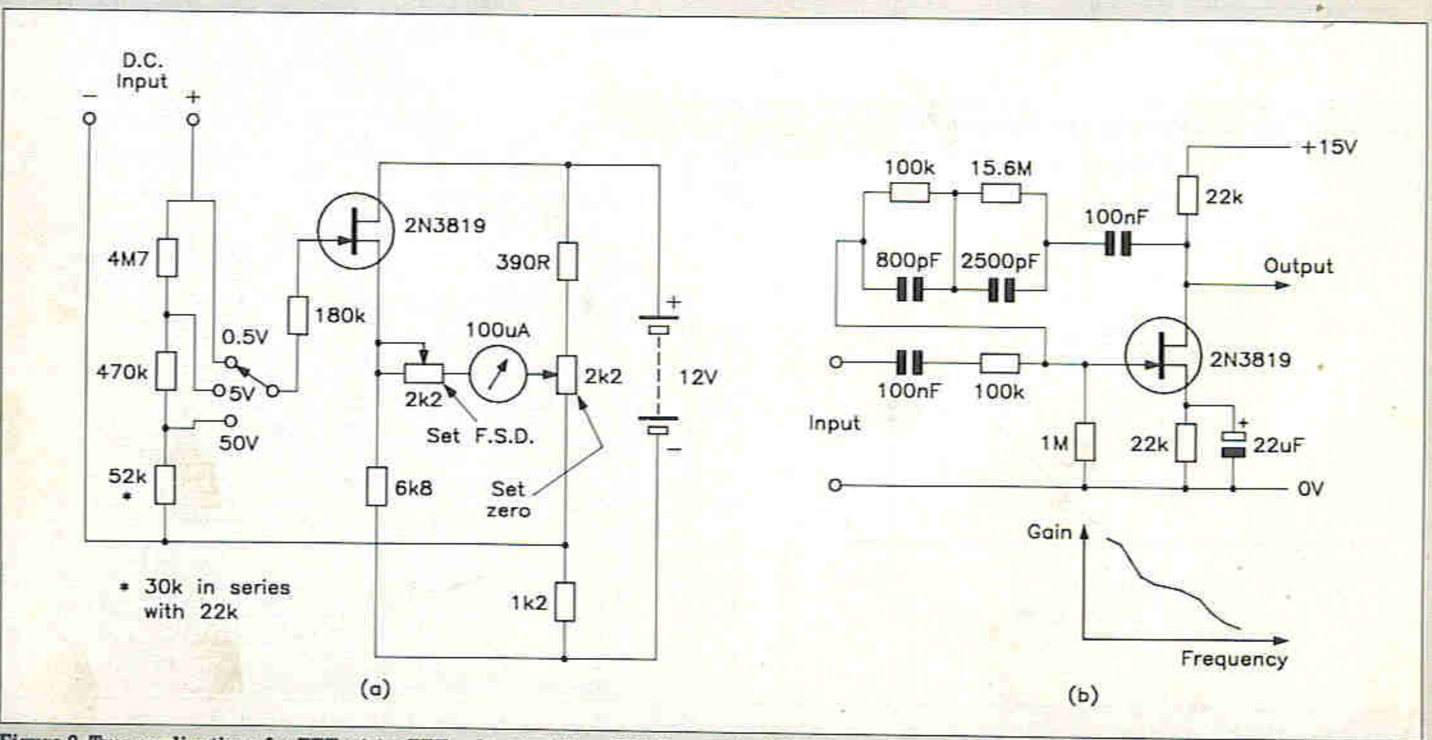


Figure 8. Two applications for FETs: (a) a FET voltmeter (b) an RIAA equalised disk pre-amplifier.

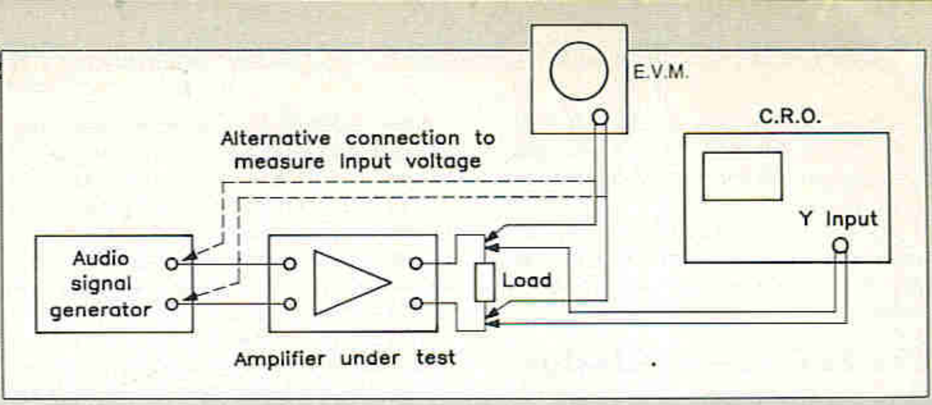


Figure 9. Test bench set-up for measuring amplifier gain.

For the moment we shall just discuss the audio-frequency type. The purpose of such an instrument is to generate sinewaves, of very low distortion levels, over a wide range of frequencies. Although referred to as an 'audio' generator, the range covered is always well in excess of the range of normal hearing. In the case of one particular type, the coverage extends from 1Hz to 1MHz. The output level must also be capable of wide variation, so as to be able to provide signals of only a few millivolts (for testing high gain amplifiers) or several volts for testing power amplifiers or even loudspeakers.

It is usual to make the selection of either frequency or amplitude the function of two controls. One is a coarse control that selects the range; the other is continuously variable within the range selected. Following telecommunications practice, the output impedance is usually a constant value of 600 ohms. An essential feature, common to all well designed signal generators, is constancy of amplitude when the frequency is varied. This is achieved by an automatic amplitude stabilisation circuit within the oscillator itself.

A further facility that is often included is the option of a square wave output.

Electronic Voltmeter

The average multimeter is limited to the range of voltages that it can accurately measure. It is limited by inadequate sensitivity when it is necessary to measure very small signals, those of the order of a few millivolts or less. It is also limited by its restricted bandwidth. In this respect, digital multimeters tend to be rather better than analogue meters. They are, after all, electronic by nature and some of them can perform well over a fairly wide range of amplitude and frequency. The specification for the instrument should be consulted to find out just what its limitations are. The analogue multimeter, on the other hand, tends to draw far too much current from the circuit under test when the measurements are of a.c. quantities. The a.c. ranges of such instruments are really suitable for measurements at power frequencies, e.g. the mains supply, but also for reading the secondary voltage of a mains transformer.

For general use in conjunction with the type of signal generator just discussed, the electronic voltmeter with analogue read-out tends to be the best choice. Its input impedance of several Megohms means that it doesn't draw any significant current from the test point. Its sensitivity means that it is, usually, capable of measuring voltages down to a few microvolts, while its bandwidth up to say 6MHz or more, frees it from the frequency restrictions of the multimeter. If there is a snag, it is that it tends to be fairly expensive. However, it is possible to construct one of a limited specification oneself, that is still capable of doing much useful work.

Cathode Ray Oscilloscope

After the acquisition of the basic tools and a multimeter, this is the instrument that the serious experimenter should put high on their shopping list. It is the most versatile instrument that one can own and is capable of a very wide range of applications indeed. Not only can it do the obvious, actually 'observe' the waveform; it can measure its amplitude and frequency as well. It can also measure phase angles between two waves, say two voltages or a voltage and a current. It is the most expensive purchase that one is likely to have to make, but it isn't that expensive when its usefulness is considered.

Virtually all oscilloscopes have at least two traces; some nowadays have three. Two trace 'scopes' allow direct comparison between two waves, a really useful feature. The vertical direction of the display is termed the 'Y' direction while the horizontal direction is termed 'X'. The direction mutually perpendicular to these two directions is termed 'Z'. This axis is straight down the centre of the tube; on a 'two dimensional' oscilloscope, the 'Z' axis is displayed by modulating beam intensity and, yes, it does have a use too, sometimes!

Each of the 'Y' inputs has its own amplifier, with variable gain, calibrated in mV/cm or V/cm. The 'X' direction is also known as the 'timebase'. The spot of light, generated by the electron beam hitting the phosphor screen at the front of the tube, is swept from left to right, then rapidly returned to the left to start a new sweep, and so on. The variable timebase control is calibrated in μs/cm, ms/cm or s/cm.

Associated with each 'Y' amplifier is a shift control; there is also one for the 'X' direction. These allow the display to be shifted around and positioned as required. Other facilities, often less well understood for some reason, are the triggering (synchronising) controls. The purpose of these is simply to synchronise the frequency of the waveform being observed with the timebase frequency. This ensures a steady display. The problem that newcomers find confusing arises because of the various options (quite essential) that the instrument maker has provided to ensure a rock steady display under a variety of conditions. This means it is necessary to understand how to set several switches in combination, perhaps a potentiometer as well, in order to get a stationary trace on the tube.

Figure 9 shows how to set up a test bench for measuring the gain of an amplifier. The signal generator supplies the input to the circuit; its value would be set up by using the EVM initially. The latter instrument is then connected across the output, as is one 'Y' input of the CRO. Measurements of the output voltage at different frequencies can then be made and the gain calculated knowing the amplitude of the input voltage. This can be repeated at various frequencies to see how the amplifier gain varies over a

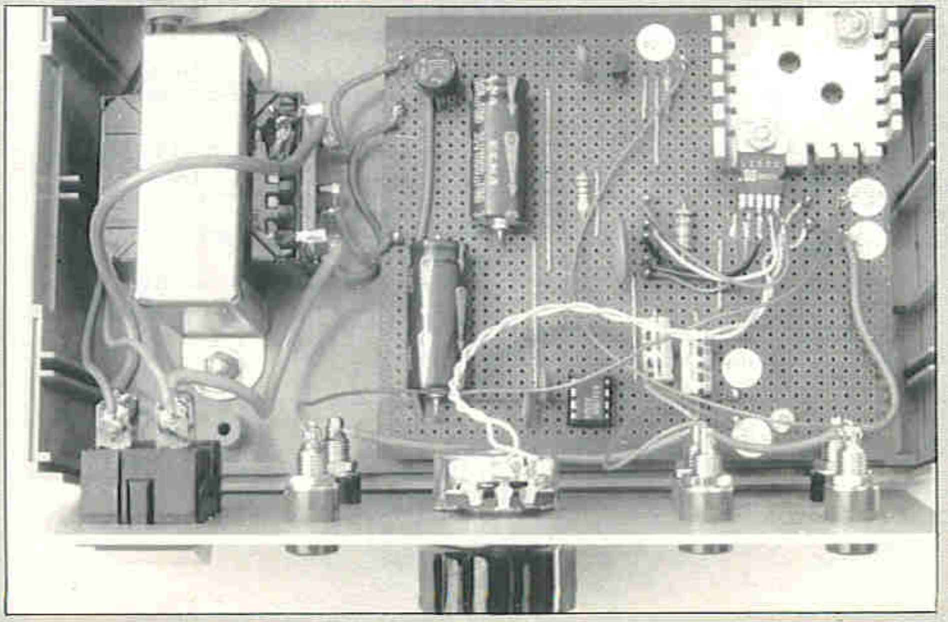


Photo 6. Plan view of fully assembled and wired power supply. Note the use of a P-clip as a cable clamp and the wiring of the mains switch.

particular frequency range. The purpose of the CRO in this case is simply to ensure that there is no significant distortion in the output waveform.

Measurements on audio amplifiers could occupy a sizeable article in its own right. This is nothing more than a brief introduction to the subject.

The Project – a versatile Power Supply

We can't do very much experimenting in electronics without suitable sources of d.c. voltage. While most TTL digital circuits require only a +5V supply at modest current and many operational amplifiers will be happy with a balanced ±15V supply, a variety of other circuits need anything from about 3V to 20V or more. This power supply design caters for all of the above cases and details are given for its construction. IC regulators are used throughout, thus minimising the component count and cost. The complete circuit diagram for this power supply is shown in Figure 10.

The circuit uses a miniature mains transformer with a dual secondary arrangement. These latter windings are connected to a bridge rectifier BR1 so as to produce a pair of unregulated d.c. outputs of equal value but opposite polarity. These voltages appear across the large value electrolytic capacitors C1 and C2 respectively. The nominal values of these voltages appear on the circuit for reference. The positive d.c. output feeds all three regulators, while the negative supply is used only for the 4195 regulator in order to develop the −15V output.

A stripboard design is given, as is a suggested layout for the front panel. The case specified will accommodate the circuit components adequately. Some flexibility has been left in the actual physical arrangements of the unit. It is stressed, however, that this project should only be undertaken when the right level of competence in soldering, etc., has been attained and/or supervisory help from a more qualified person is available. Particular care should be taken with the mains wiring of the unit; the mains cable should be securely anchored to relieve stress on the transformer connections.

Testing the Completed Unit

When wiring is complete, a visual check should be carried out to detect any errors, bad joints, etc. Make sure that the electrolytic capacitors are the right way round and that the rectifier and transformer are correctly connected. Particular care always has to be taken in the case of mains-operated equipment. When satisfied that all ought to be well, the time has come to switch on. If this act produces nothing other than a comforting silence, a voltmeter should be used to check the outputs of the +5V and ±15V sections. Then the variable output should be checked, giving an approximate range from 3 − 20V. The variable control should, logically, produce an increasing voltage as it is rotated clockwise. If all is well, the unit can be boxed up, the terminals marked with Letraset to indicate the outputs and you now have your own 'hand-built' power supply ready for use. Perhaps just the first of many such items. Apart from saving substantially on the cost of factory made equipment, there is the satisfaction aspect, as well as the increasing self-confidence.

Appendix

1. Energy Stored In A Capacitor:

The capacitor is able to store energy in the form of an electrostatic field between its plates. While it is storing energy, a voltage exists between its terminals. The amount of stored energy is calculated from:

The energy W (Joules) stored in a capacitor of C (Farads) with a terminal voltage V (Volts) is given by:

$W = (1/2) \times C \times V^2$

Example: a 10μF capacitor with a terminal voltage of 20V is storing:

$0{\cdot}5 \times 10 \times 10^{-6} \times 20^2$
$= 0{\cdot}5 \times 10^{-5} \times 400$
$= 2$ mJ (milli-Joules)

2. Energy Stored In An Inductor:

The inductor (coil) is able to store energy in the form of an electromagnetic field within its turns. While it is storing energy, a current is flowing through it. The amount of stored energy is calculated from:

The energy W (Joules) stored in an inductor of L (Henries) with a current of I (Amperes) flowing is given by:

$W = 0{\cdot}5 \times L \times L^2$

Example: a 20H coil carrying a current of 5A is storing:

$0{\cdot}5 \times 20 \times 5^2$
$= 0{\cdot}5 \times 20 \times 25$
$= 250$ J (Joules)

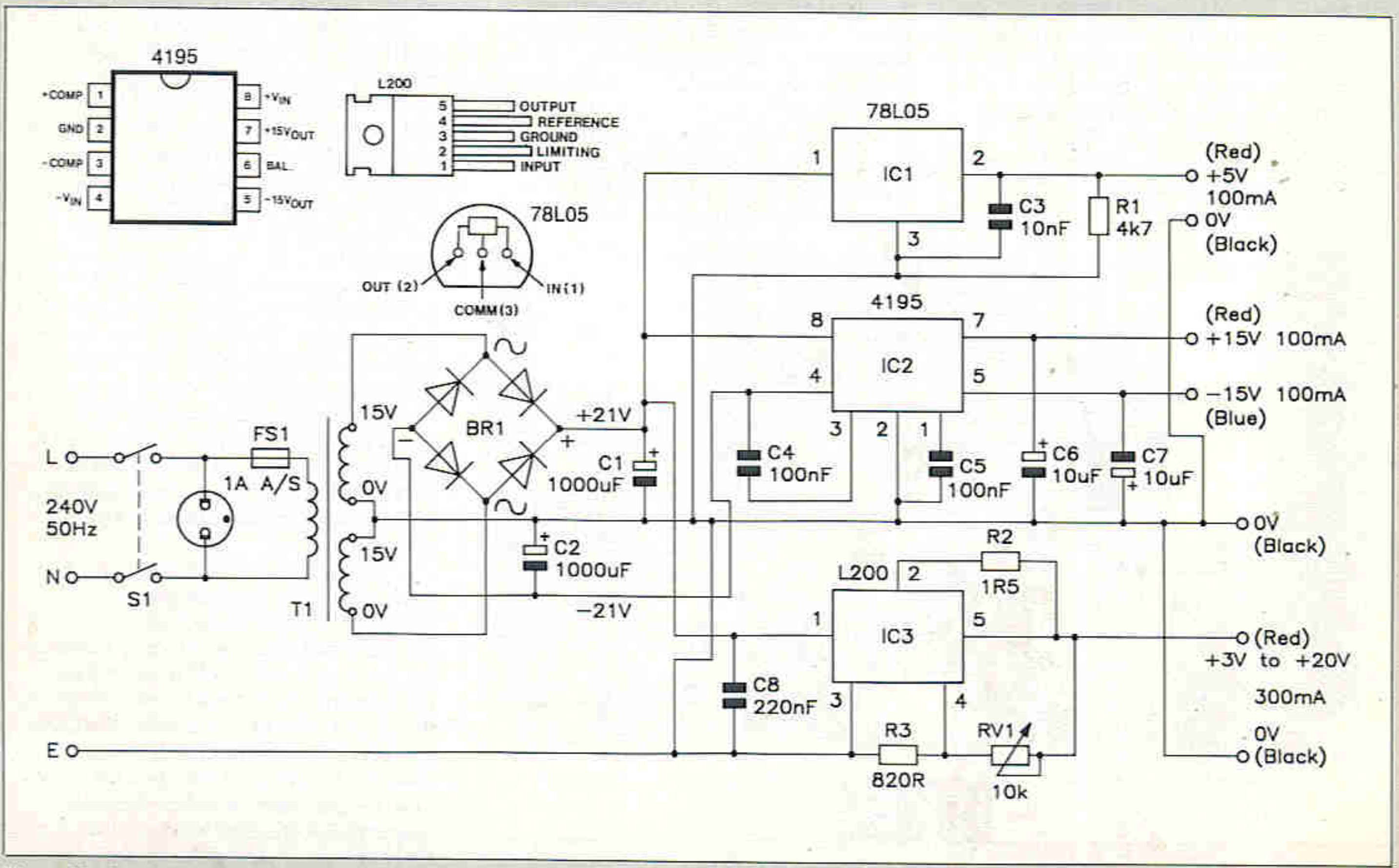


Figure 10. Circuit diagram for the power supply project.

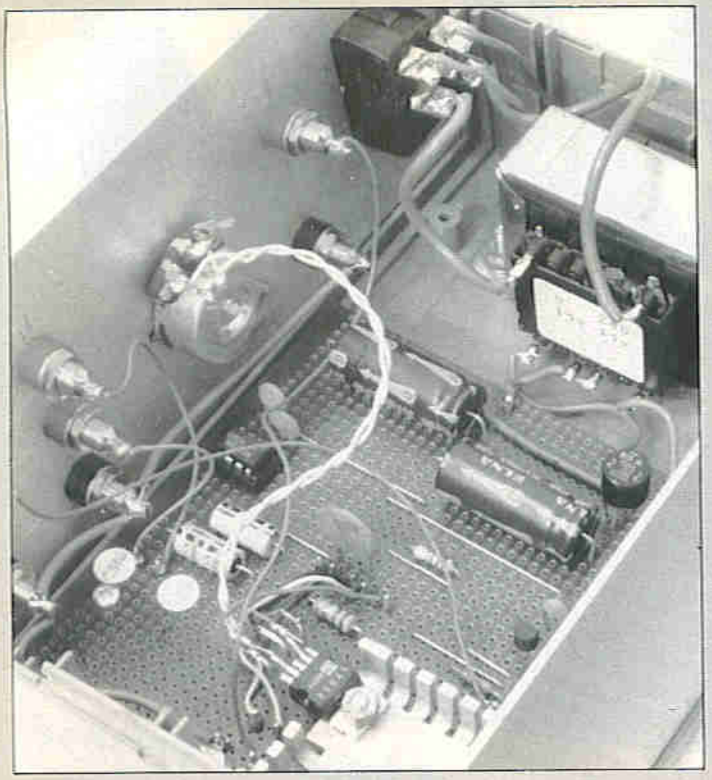


Photo 7. Internal view of power supply showing front panel wiring.

POWER SUPPLY PARTS LIST

Resistors			
R1	4k7		(M4K7)
R2	1·5R		(M1R5)
R3	820R		(M820R)
RV1	10k lin. pot.		(FW02C)
Capacitors			
C1,2	1000µF 35V Axial Electrolytic	2 off	(FB83E)
C3	10nF Disc Ceramic		(BX00A)
C4,5	100nF Disc Ceramic	2 off	(BX03D)
C6,7	10µF 25V Axial Electrolytic	2 off	(FB22Y)
C8	220nF Disc Ceramic		(JL01B)
Semiconductors			
IC1	78L05		(QL26D)
IC2	4195		(XX02C)
IC3	L200		(YY74R)
Miscellaneous			
Transformer T1 0-15V; 0-15V 10VA			(LY03D)
Bridge rectifier BR1 type W01			(QL38R)
Case			(LQ09K)
Switch S1			(YR70M)
Fuseholder 20mm			(RX96E)
Fuse 1A A/S			(WR19V)
Knob			to suit
4mm Socket, red		3 off	(HF73Q)
4mm Socket, black		3 off	(HF69A)
4mm Socket, blue		1 off	(HF70M)

TAKE YOUR PICK COMPETITION WINNER!

Presentation of the Oscilloscope to Lorne Mason (left) by Maplin's Technical Author Robert Ball.

In the December '89 – January '90 Issue of 'Electronics – The Maplin Magazine' we set the 'Take Your Pick Competition'. Entrants had to correctly identify three everyday electronic components and suggest a subject for an article or feature that they would like to be included in the magazine. A choice of five superb prizes were available for the winner to 'take their pick' from. The prizes were, a Triple Trace 20MHz Oscilloscope; a 6-Channel Mixing Desk; a Laser Tube, PSU & Controller; a Remote Control Computer Graphic Equaliser or a VHF FM 2m 45W Transceiver.

The correct answers were as follows:

1) 50Ω N Series Male Coaxial Connector.
2) 0.25W Horizontal Mounting Carbon Preset.
3) 2200µF 63V Snap-in Electrolytic Capacitor.

The winner was 25 year old Lorne Mason from Ilford, Essex, who correctly identified the three components and gave the following answer to the supplementary question, I would like to see an article on… 'The electronics behind electronic fuel injection and management systems in cars.' This answer, was in the judges opinion, the best suggestion. The editorial team are now searching the length and breadth of the country to collate information for an article on car electronic management systems, watch this space!

Lorne has been a Maplin customer since 1980, he first became interested in electronics some 8 years earlier at the age of 7. Apart from being a keen hobbyist, he also excelled at school and university; with qualifications to the tune of 10 GCE 'O' Levels, 2 GCE 'A' Levels and a Bachelor of Science Honours Degree. He currently works as a Broadcast Engineer for the BBC World Service at Bush House in London, where he maintains all manner of studio electronics and transmission equipment; encompassing analogue, digital and radio frequency circuitry. Not surprisingly, Lorne also holds a radio amateur's broadcasting license. With his interest in radio, we thought he would choose the VHF FM 2m 45W transceiver, but instead he chose the Triple Trace 20MHz Oscilloscope; which he said would be of great worth when designing and building electronic devices.

Lorne has built quite a number of Maplin kits, and when he got engaged to his fiancée, Sarah, he threw a party with the sound system built almost exclusively from Maplin parts! The concrete lined loudspeaker cabinets (which take two people to lift) are fitted with 12in 150W Big Cat loudspeakers, 50W bullet tweeters and HPX2 high power crossovers. Perhaps a future design for the magazine?

NICAM STEREO TV TUNER UNIT

Part Two by C.S. Barlow

Features

- ★ Power input protection
- ★ SCART, DIN and Phono sockets
- ★ Push-button function switches
- ★ Superbly finished case
- ★ Voltage synthesis tuning system
- ★ LED indicators

Resumé

In Part One of this article, a detailed description of circuit operation was given. In Part Two of this article we present full constructional details for the NICAM Stereo Tuner Accessory Kit which together with the Decoder and TV Tuner Kits build-up into the complete TV Tuner Unit.

PCB Assembly

For general information on soldering and assembly techniques please refer to the 'Constructors Guide' (stock code XH79L) included in the Maplin kit. The PCB's have a printed legend to assist you in correctly positioning each component, see Figure 6. Removal of a misplaced item is quite difficult so please double-check each component type, value and its polarity where appropriate, before soldering! The following instructions give some more specific assembly information relative to this kit:

Socket PCB

1) When fitting the PCB mounted sockets SK1 to SK6 make certain that they are pushed down firmly on to the surface of the board.
2) After soldering in the thyristor, TH1, bend it down so its metal tag is resting on the PCB.

Switch PCB

1) When fitting the IC socket, ensure that the notched end matches the block on the PCB.
2) Following the instructions in Photos 1, 2 and 3 convert the locking action of four of the 2-pole latch switches in to momentary action.
3) With its two tapped M3 fixing holes facing forward, fit a single latch bracket to a locking action switch and install it at S1.
4) Repeat this assembly using a momentary action switch and install it at S2.
5) With the two tapped M3 fixing holes of the 6 way latch bracket facing forward, install two locking action switches at the S8 and S12 positions, see Figure 7.
6) DISCARD one of the 3 way latching bars and the bridging piece, see Figure 7.
7) Place the other 3 way latching bar inside the 6 way latch bracket at the S9, 10 and 11 positions, see Figure 7.
8) Next, install the switches, see Figure 7.
9) Position the leaf spring at the end switch S11 and secure it by bending down the two fixing lugs, see Figure 7.
10) Test the interlocking action of the switches before fitting the completed

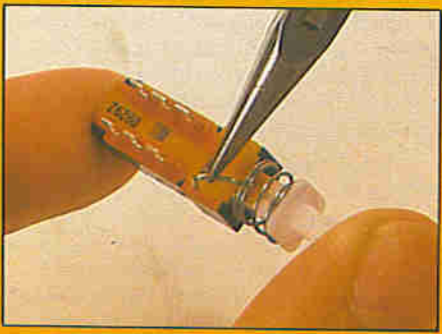


Photo 1. Remove the retaining clip keeping the spring-loaded plunger pushed in.

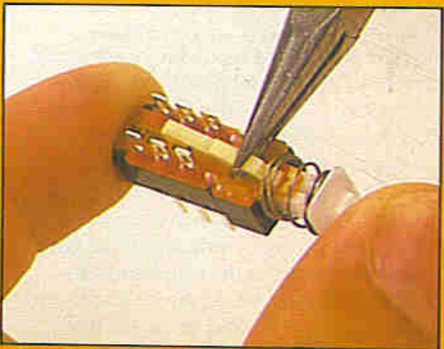


Photo 2. Insert plastic non-latching retainer.

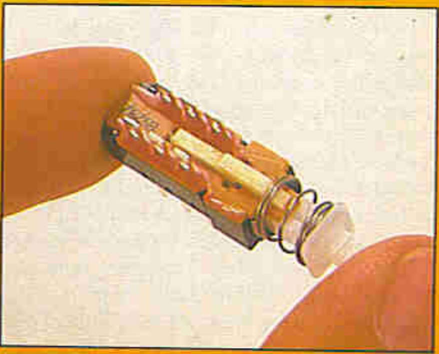


Photo 3. Switch ready for mounting on 6 way bracket.

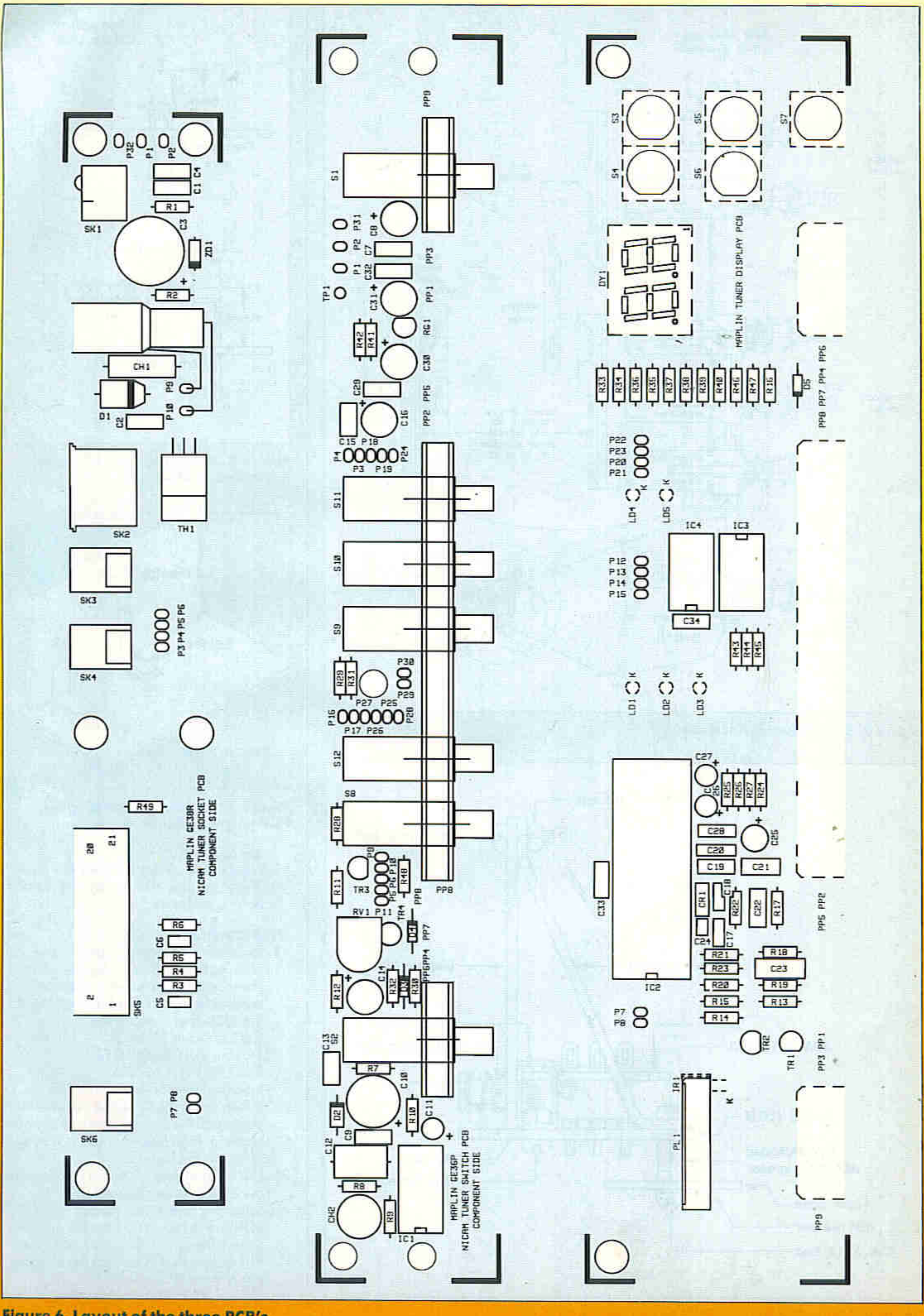


Figure 6. Layout of the three PCB's.

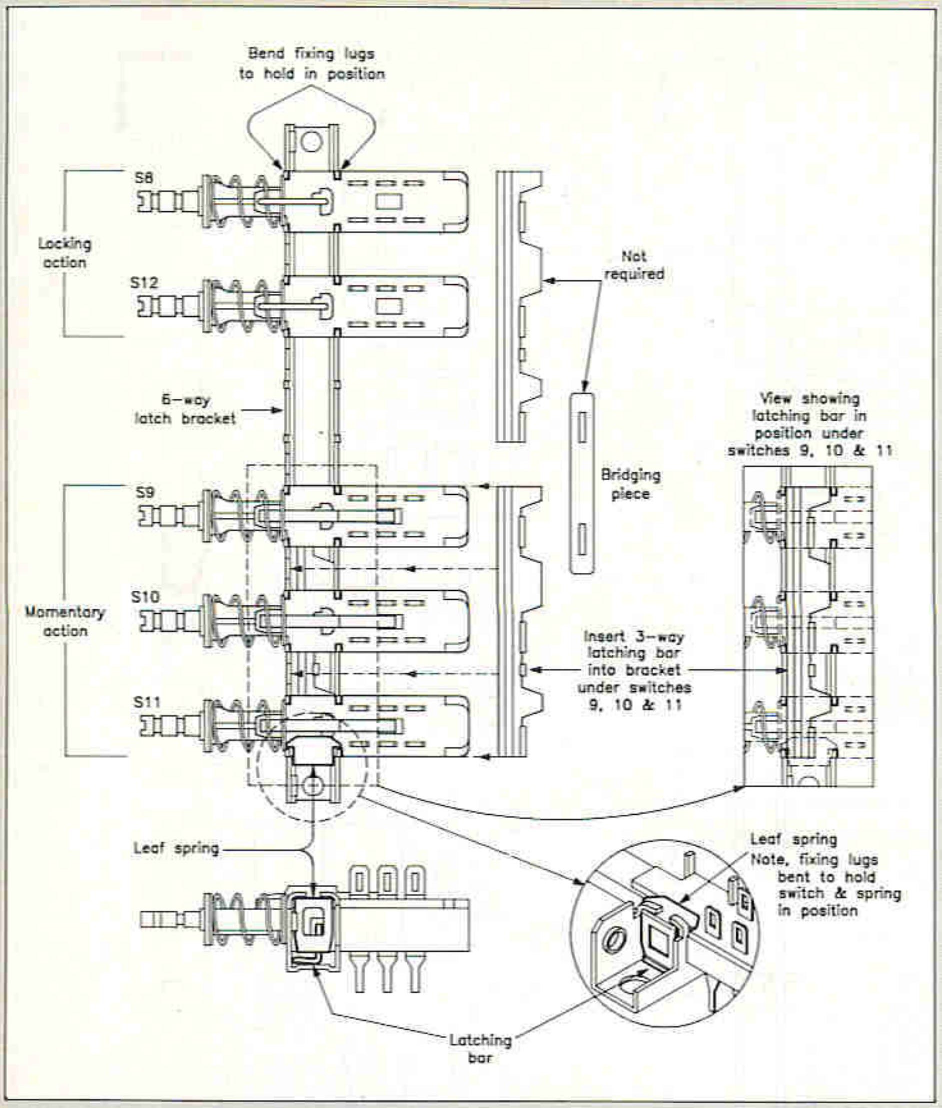


Figure 7. 5-Way Switch Assembly.

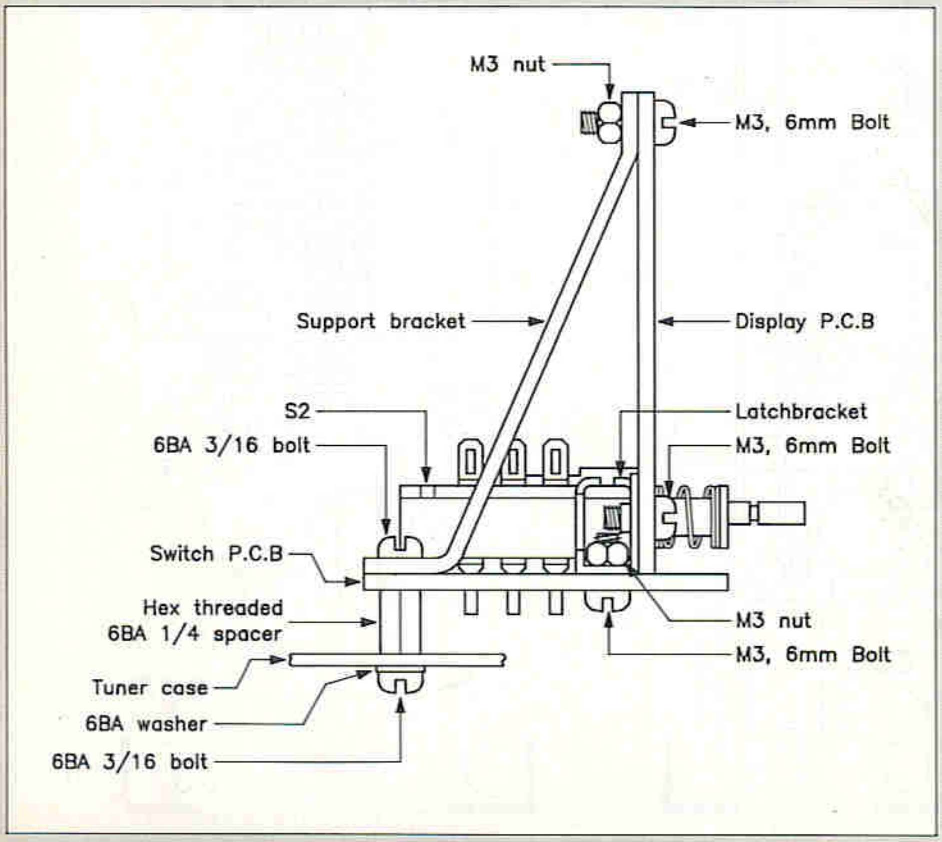


Figure 9. Fitting the Display PCB to the Switch PCB.

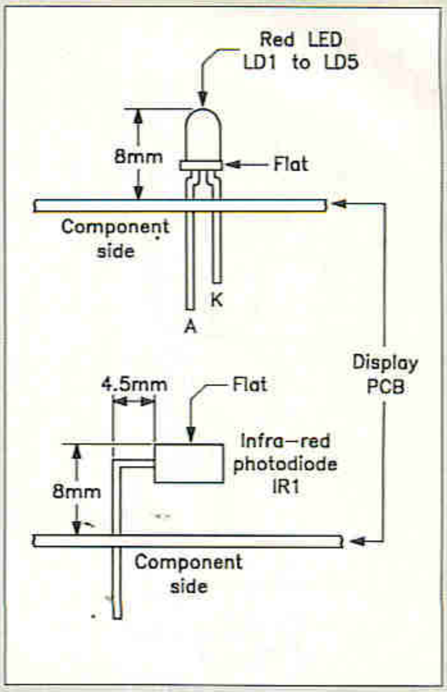


Figure 8. Mounting the LED's and Infra-Red Photodiode.

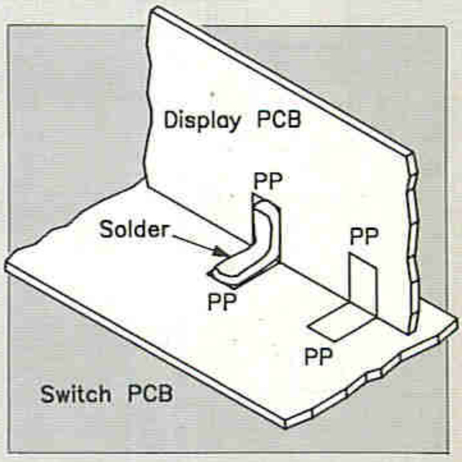


Figure 10. Soldering the Display PCB to the Switch PCB.

unit to the PCB.

11) Ensure that all the switches are down firmly on the surface of the board before soldering.

Display PCB

1) Examine the printed legend with care as a dotted outline indicates when a component is to be mounted on the other side of the board. This applies to the following components:
   Click switches S3 to S7.
   Double digit display DY1.
   Red LED's LD1 to LD5.
   Infra-red photodiode IR1.
2) When fitting the IC sockets ensure that you install the appropriate one at each position, matching the notch with the block on the board.
3) DO NOT install IC2 until it is called for during the testing procedure.
4) Referring to the information provided in Figure 8, mount LD1 to LD5 and IR1.
5) When fitting the 'Minicon' connector PL1 ensure that its locking tag is facing away from PP3 and PP9.
6) Fit six M3 nuts inside the switch brackets and six M3, 6mm bolts

through the under-side of the switch PCB, see Figure 9.

7) Position the display PCB so that the numbered PP solder pads all line up with the PP pads on the switch PCB.
8) Fasten the two boards together using six M3 6mm bolts, see Figure 9.
9) Solder the PP pads together as shown in Figure 10.
10) Position the display PCB support bracket (stock code JR72P) at the fixing hole near to S3 on the display board.
11) Secure it with an M3 nut and an M3 6mm bolt, see Figure 9.
12) The other end of the support bracket is secured using the 6BA hardware during the final assembly procedure.

This completes the assembly of the three PCB's 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 boards do not have any trimmed component leads standing proud by more than 3mm, as this may result in a short circuit.

Wiring

Before commencing the wiring, arrange outside of the case the accessory, tuner and decoder PCB's into their final working positions. A wiring diagram showing all the interconnections is given in Figure 11. An additional wiring chart is provided in Table 2 which has differently shaped symbols to indicate the type of cable used for each connection. This connection is made where the horizontal row and vertical column crosses over the symbol, i.e. socket PCB P1 to switch PCB P1 using ribbon cable.

The majority of interconnections running between the PCB's are made using different coloured groups of ribbon cable. This simplifies the tracing of separate connections, just in case there is a fault in any given part of the completed unit. No specific colour has been designated for each ribbon wire connection, it is entirely up to you. Strip off from the main 10 way group whichever number of wires are required for each installation. The wire

NICAM Tuner Accessory Kit Wiring Chart			Socket PCB						Switch PCB																					Display PCB										NICAM Decoder PCB	
																																								PL2	
			P3	P4	P5	P6	P7	P8	P1	P2	P3	P4	P5	P6	P9	P10	P11	P16	P17	P18	P19	P24	P25	P26	P27	P28	P29	P30	P31	P7	P8	P12	P13	P14	P15	P20	P21	P22	P23	1	2
Socket PCB		P1							△																																	
		P2								△																																
		P32																											△												
NICAM tuner PCB	PL1	1												△																												
		2											△																													
		3																													△											
		4																												△												
		5																																								
		6														△																									
	PL2	1																																						⊡	
		2																																							■
	PL3	1					⊡																																		
		2						■																																	
	PL4	1																					⊟																			
		2																						□																		
		3																							⊟																	
	PL5	1															△																									
		2																																								
NICAM decoder PCB	PL1	1									△																															
		2										△																														
	PL3	1																																	△								
		2																																								
		3																																								
		4																																△									
		5																																								
		6																															△										
		7																																								
		8																														△											
	PL4	1																																								
		2																																								
		3																		△																							
		4																			△																						
		5																																								
		6													△																										
		7																																								
		8																				△																					
	PL5	1																										⊟													
		2																									□														
		3																								⊟															
		4																									□														
	PL6	1	⊟																																					
		2		□																																				
		3			⊟																																			
		4				□																																		
	PL7	1																△																								
		2																	△																							
		3																																				△			
		4																																					△		
		5																																		△					
		6																																			△				

Cables

△ Ribbon (Any colour)

□ Screen } Audio screened cable
⊟ Centre

■ Screen } R.F (75Ω) screened cable
⊡ Centre

Table 2. Wiring Chart.

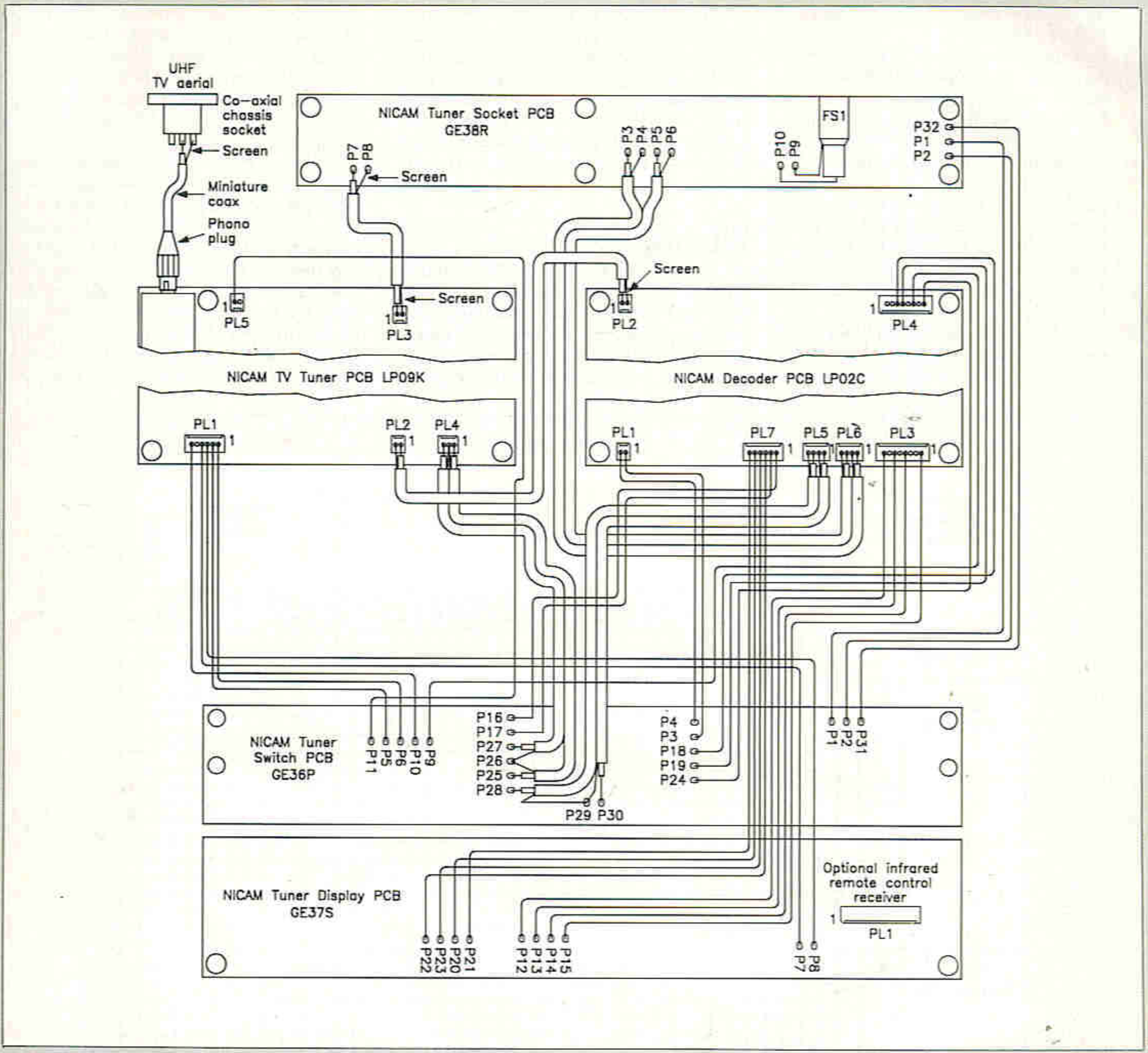


Figure 11. Wiring.

connections to the main NICAM boards are made using Minicon connectors supplied in each kit and the method of installing them is shown in the accompanying instructions.

When using the screened 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. From the tuner kit (stock code LP09K), use the phono plug and a short length (approximately 100mm) of miniature coaxial cable to make up the aerial input lead. Push the phono plug firmly into the socket on the tuner module. DO NOT wire to the coaxial TV aerial socket at this time.

Finally, install two 35mm lengths of ribbon wire at P9 and P10 on the switch PCB. DO NOT wire up the fuse holder until it is called for during the final assembly stage. This completes the wiring of the PCB's and you should now check your work very carefully making sure that all the solder joints are sound.

Final Assembly

The PCB's are designed to fit into a pre-drilled and printed case which is included in the NICAM tuner accessory kit, or is available separately using the Maplin stock code XM81C. Before installing the wired-up boards you must complete the following:

1) Remove the black painted lid from the case.
2) Follow the instructions given in Figure 12, and cut the red display filter into four pieces.
3) With a good quality glue (impact adhesive) attach them to the inside front of the case at the positions shown in Figure 12.
4) Using a 6BA $^3\!/_{16}$inch bolt with a washer under its head, install the hexagonal PCB spacers, see Figure 9.
5) Stick onto the base the four square rubber feet.

Carefully position the PCB's inside the case so that their fixing holes line up with the hexagonal spacers. Secure the boards with the 6BA $^3\!/_{16}$inch bolts and washers. DO NOT use a washer on the display support bracket, see Figure 9. Referring to Figure 13, mount the TV aerial socket and connect up the coaxial lead coming from the tuner board, see Figure 11. The SCART socket SK5 is held in position using the M3 hardware as shown in Figure 13.

Next install the fuse holder on to the back panel and solder its terminals to the wires coming from P9 and P10 on the socket PCB, see Figure 11. DO NOT fit the 1A fuse until it is called for during the testing stage.

Fit the five square white caps on to the channel, tuning and store click switches S3 to S7. Finally, push on the coloured rectangular buttons in the following order:

White – Audio Tune (S2).

Grey – NICAM/FM (S8) and UK/Cont (S12).

Grey – M1+M2 (S9), M1 (S10) and M2 (S11).

Red – Power On/Off (S1).

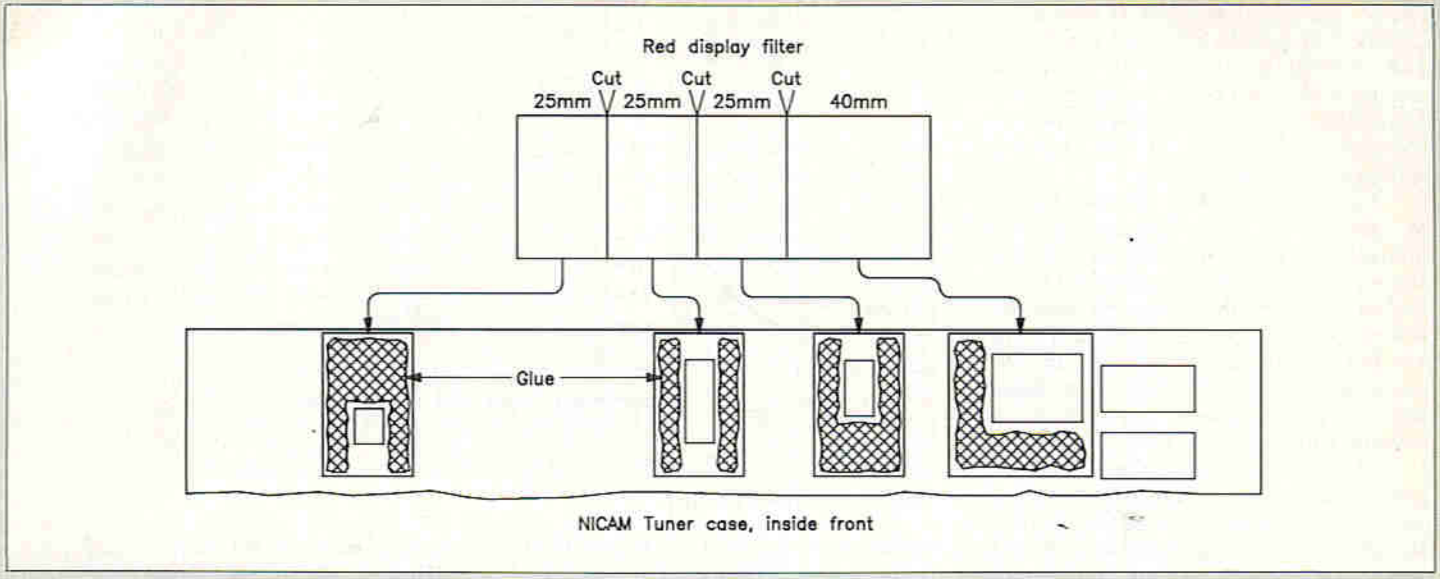


Figure 12. Fitting the Red Display Filter.

Testing and Using

In the following tests it is assumed that you have already successfully built, tested and aligned the NICAM tuner (stock code LP09K) and decoder (stock code LP02C). The DC tests for the accessory boards can be made with a minimum of equipment. You will need a multimeter and a regulated +12V DC power supply capable of providing at least 600mA (stock code YZ21X). 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. Before commencing the tests check the following:

1) Fuse FS1 is NOT fitted in the fuse holder.
2) Power switch S1 is in its OFF position.
3) NICAM/FM (S8) and UK/Cont (S12) are both OUT.
4) M1+M2 (S9) is pushed IN.
5) IC1 on the switch board is installed.
6) RV1 on the switch board is set to its half way position.
7) IC3 and 4 on the display board are both installed.
8) IC2 on the display board is NOT fitted.

The first test is to ensure that there are no short circuits before you connect the DC supply. Set your digital meter to read ohms on its 2kΩ (Diode Test) range. With the red lead on P10 and the black on P1 a reading greater than 2kΩ should be present. When the test leads are swapped over a reading of approximately 500Ω should be observed. However, this test condition may be reversed when using an analogue multimeter. Repeat this test with the power switch S1 pushed in and with the probes either either way round you should now observe a reading of approximately 250Ω.

Next select a suitable range on your meter that will accommodate a 700mA DC current reading. Before connecting the meter do the following:

1) Check that no fuse is fitted in the holder.
2) Check that the power switch S1 is OFF (out position).
3) Check that IC2 on the display PCB is NOT fitted.
4) Remove the power plug PL1 for the NICAM tuner board.
5) Remove the power plug PL1 for the NICAM decoder board.
6) Check the polarity of your 12V DC supply, positive to the centre pin of the 2.5mm plug.

Now connect the test leads to the terminals on the fuse holder, red to the side terminal (P9) and black to the end terminal (P10). When the power is applied to SK1 no standing current should be registered until the power switch S1 is pushed in. When switched on an initial reading of approximately 10mA should be observed and as the following is reconnected this current drain should increase:

1) Connect PL1 on the NICAM tuner board, current reading approximately 230mA.
2) Connect PL1 on the NICAM decoder board, current reading approximately 425mA.

As the power to the decoder PCB is connected the FM LED, LD5, should light up. Disconnect your multimeter and install a one amp fuse in to the holder.

Now set your meter to read DC volts. All voltages are positive with respect to ground, so connect your negative test lead to a convenient 0V ground point on the unit, i.e. PP2 on the switch/display PCB's. With the power connected and the unit switched on the following approximate readings should be present:

Circuit ref.	Voltage (+V)
P1,4,6,24,25 – 30	0
P2,3,5,20,31,32,PP4,PP9	12
P7	0·4
P8	33
P9	4·5
P10,23	0·6
P11	6·5
P12 – 15,18,PP5	5
P16	9·7
P17,19 and PP7	1·4
P21	10·3
P22	2·6

Adjust the preset resistor RV1 on the switch PCB to obtain a voltage reading of precisely +25V on TP1 and PP1.

Turn off the unit and install IC2 on the display board making certain that all its pins go into the socket and the pin one marker is at the notched end. When powered up channel number one should be indicated by the double digit display DY1. Keep the channel up button (S4) pressed in and every half second this number should increase by one until it reaches sixteen. The supply current will increase from approximately 475mA to 537mA as more segments of the display are used, i.e. numbers 8 and 16. Test the channel down button (S3) and observe the decreasing numbers which will flip back to sixteen as channel one is passed.

Next, connect your digital DC volt meter to P7 on the display board. Push in the tune up button (S6) and observe the increasing positive voltage which should

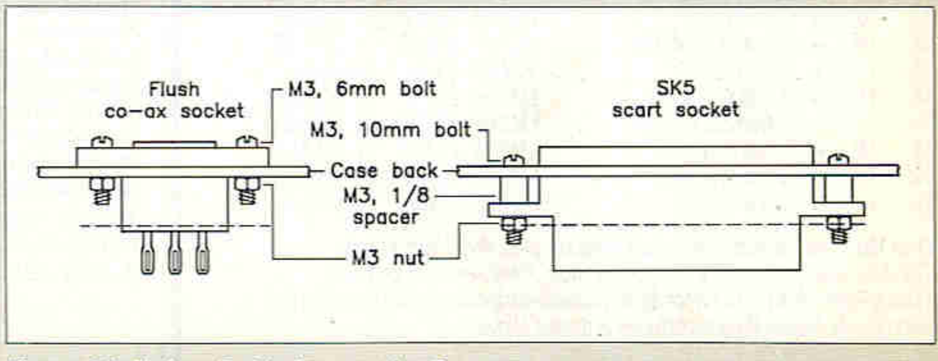


Figure 13. Fixing the Sockets to the Case.

reach approximately +30V before dropping back to +0·4V. When the tune down button (S5) is pressed the opposite condition should occur. If you press the store button, then that voltage present on P7 will be assigned to the currently displayed channel number.

The best way to fully test the tuning is to connect up your TV aerial, video monitor and audio amplifier to the unit. However, if your stereo equipment has a SCART connector then only one multiway interconnecting lead is required, see Figure 14. The audio and video cables used to make up the SCART lead must have separate screening which connects to the relevant common return pins.

As you tune through the TV stations you should find the strongest and clearest picture for any given channel, then store it. The audio signal is automatically muted when the tuning buttons are used. However, this function can be overridden by pushing in the audio tune switch S2. This will not disable the interstation muting but will allow you to listen to all the spurious sounds as the station is tuned across. Why? Because if you are only using the unit with an audio amplifier you would never know if a TV station was being tuned through.

Once you have successfully tuned in and stored all your local TV stations, hopefully some with NICAM, test the NICAM/FM switch S8. As this switch is pushed in the NICAM LED, LD4, should go out and the FM LED, LD5, should light up.

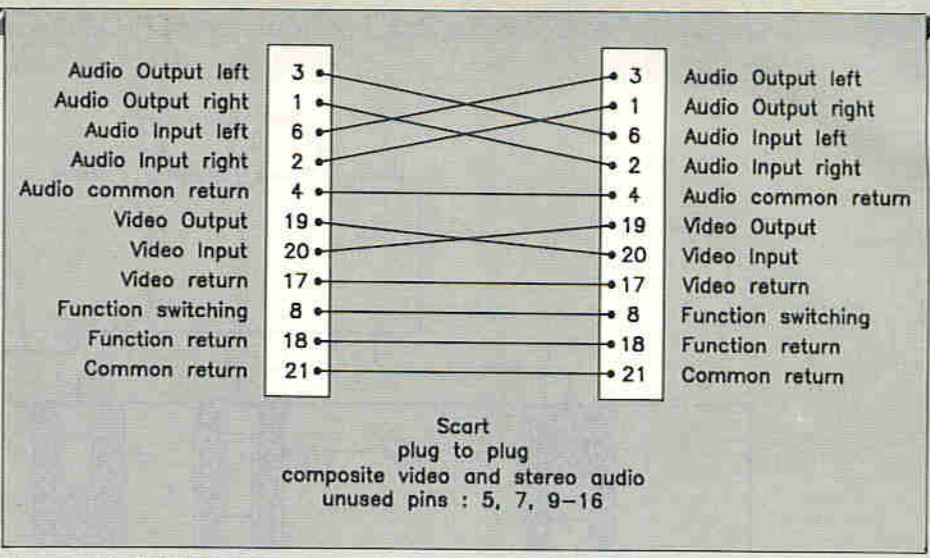


Figure 14. SCART Lead.

When receiving British TV stations, the FM sound switch S12 should be in the UK position (out). However, if you are fortunate enough to receive continental TV, try selecting the Cont option.

Normally when receiving a NICAM signal, the stereo LED LD1 will be on, although the programmes sound track can still be in mono. The state of this LED and the mono 1 and mono 2 LED's is controlled by the engineering staff at the TV station. Sometime in the future it is hoped that using the two channel mono mode, bilingual programmes can be made available. When, or if, this happens your receiving equipment must have the facility to select one or other of the mono sound tracks. When pushed in, the M1+M2 switch (S9) will put the mono 1 signal on the left channel and the mono 2 signal on the right. The M1 switch (S10) puts the mono 1 signal on to both channels while the M2 switch (S11) selects the mono 2 signal.

Finally, to test the reverse polarity and over volts protection circuit you must have some spare one Amp 20mm fuses. If your power supply has its own short circuit protection then the fuse in the project may not blow under test. This condition is acceptable as it offers the same degree of protection to the unit. Before commencing the test, do the following:

MAPLIN'S TOP TWENTY KITS

THIS	LAST MONTH		DESCRIPTION OF KIT	ORDER CODE	KIT PRICE	DETAILS IN PROJECT BOOK
1.	(1)	▲▼	Digital Watch	FS18U	£1.98	Catalogue
2.	(3)	▲	150W MOSFET Amplifier	LW51F	£19.95	Best of E&MM
3.	(4)	▲	Car Battery Monitor	LK42V	£8.95	Best of E&MM
4.	(2)	▼	Live Wire Detector	LK63T	£3.95	14 (XA14Q)
5.	(8)	▲	I/R Prox. Detector	LM13P	£9.95	20 (XA20W)
6.	(7)	▲	Partylite	LW93B	£9.95	Best of E&MM
7.	(9)	▲	Siren Sound Generator	LM42V	£3.95	26 (XA26D)
8.	(5)	▼	Mini Metal Detector	LM35Q	£5.25	25 (XA25C)
9.	(10)	▲	TDA2822 Stereo Power Amp	LP03D	£6.45	34 (XA34M)
10.	(17)	▲	Car Burglar Alarm	LW78K	£9.95	Comp 2 (XC02C)
11.	(14)	▲	8W Amplifier	LW36P	£5.95	Catalogue
12.	(13)	▲	PWM Motor Driver	LK54J	£9.45	12 (XA12N)
13.	(6)	▼	Watt Watcher	LM57M	£3.95	27 (XA27E)
14.	(16)	▲	U/Sonic Car Alarm	LK75S	£19.95	15 (XA15R)
15.	(12)	▼	15W Amplifier	YQ43W	£6.45	Catalogue
16.	(11)	▼	LM386 Kit	LM76H	£3.75	29 (XA29G)
17.	(–)	▲	I/R Remote Switch	LM69A	£18.95	33 (XA33L)
18.	(15)	▼	Digital Playback	LM85G	£14.95	31 (XA31J)
19.	(–)	▲	Stereo Pre-Amp	LM68Y	£5.25	33 (XA33L)
20.	(–)	▲	50W Amplifier	LW35Q	£18.45	Catalogue

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

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

/// Maplin

*Do you **Enjoy your work?***
Or would you prefer to
Work at what you enjoy?

If you are an electronics enthusiast and looking for an interesting career with a future, Maplin has the answer.

We currently have vacancies for

JUNIOR AND SENIOR TECHNICAL SALES STAFF

At SOUTHAMPTON and our new store shortly to open in BRIGHTON

These vacancies are being created as a result of the Maplin expansion program and offer real prospects up to and including Branch Management.

A knowledge of sales, although an asset, is not essential. But, to become part of the team you do need to be self motivated and have a cheerful personality. Applicants should also be smart and have a knowledge of electronic components.

We offer excellent working conditions and job security, plus a good salary with commission and a realistic pension scheme.

Apply in writing enclosing CV to: David Snoad, P.O. Box 3, Rayleigh, Essex. Or for further information, ring 0702 554155.

If you are seeking an interesting career in a Hi-Tech environment then contact us

NOW!

1) Switch off the power (S1 out).
2) Disconnect the power supply from the unit.
3) Check that a 1A fuse is fitted in the holder.
4) Set your multimeter to read DC volts and connect it to P2 on the switch PCB.

Now reconnect the power supply but in the reverse polarity, i.e. negative to the centre pin of SK1. No negative or positive voltage should be registered by the meter and on inspection you should find that the 1A fuse has blown.

To test the over volts protection circuit you must have access to a bench power supply which has a continuously variable voltage output rated at 1A or more. With your multimeter still connected to P2, slowly advance the voltage and as you reach approximately +15V the circuit should fire, blowing the fuse.

Future Development

In a future part of this series we will present an infra-red remote control system which will allow you to change channel and adjust the audio level from the NICAM tuner unit. Watch this space!

Acknowledgement:

Maplin Electronics would like to thank the staff at Radio Rentals Ltd, Hockley, for their assistance.

NICAM TUNER ACCESSORY KIT PARTS LIST

RESISTORS: 0.6W 1% Metal Film

R1,16,25,29, 30,31	10k	6	(M10K)
R2,5,6,46,47	2k2	5	(M2K2)
R3,4	22k	2	(M22K)
R7,12	2R2	2	(M2R2)
R8	1R	1	(M1R)
R9	180R	1	(M180R)
R10,22	1k5	2	(M1K5)
R11,32	27k	2	(M27K)
R13,48,49	4k7	3	(M4K7)
R14,24	100R	2	(M100R)
R15	6k8	1	(M6K8)
R17	82k	1	(M82K)
R18	56k	1	(M56K)
R19,20	33k	2	(M33K)
R21	3k9	1	(M3K9)
R23	3k3	1	(M3K3)
R26	12k	1	(M12K)
R27	5k6	1	(M5K6)
R28,43,44,45	1k	4	(M1K)
R33	330R	1	(M330R)
R34-40	680R	7	(M680R)
R41,42	10R	2	(M10R)
RV1	4k7 Hor Encl Preset	1	(UH02C)

CAPACITORS

C1,2,4,7,9,19, 28,29,32,33,34	100nF 16V Minidisc	11	(YR75S)
C3	2200µF 16V PC Electrolytic	1	(FF60Q)
C5,6	100pF Ceramic	2	(WX56L)
C8,30,31	220µF 16V PC Electrolytic	3	(FF13P)
C10	1000µF 16V PC Electrolytic	1	(FF17T)
C11	1µF 100V PC Electrolytic	1	(FF01B)
C12	2200pF Polystyrene	1	(BX37S)
C13,15	100nF Monores	2	(RA49D)
C14,16	100µF 35V PC Electrolytic	2	(JL19V)
C17,18	220pF Ceramic	2	(WX60Q)
C20	4n7F Poly Layer	1	(WW26D)
C21,22	100nF Poly Layer	2	(WW41U)
C23	150nF Poly Layer	1	(WW43W)
C24	47pF Ceramic	1	(WX52G)
C25	47µF 25V PC Electrolytic	1	(FF08J)
C26,27	10µF 50V PC Electrolytic	2	(FF04E)

SEMICONDUCTORS

D1	1N5400	1	(QL81C)
D2	1N4001	1	(QL73Q)
D3,4,5	1N4148	3	(QL80B)
ZD1	BZY88C15	1	(QH18U)
IR1	Infra-red Photodiode	1	(YH71H)
TR1	BC328	1	(QB67X)
TR2	2N3903	1	(QR39N)
TR3,4	BC548	2	(QB73Q)
TH1	C106D	1	(QH30H)
IC1	µA78S40	1	(UF37S)
IC2	M491BB1	1	(UL60Q)
IC3	74LS04	1	(YF04E)
IC4	74LS11	1	(YF09K)
RG1	µA78L05AWC	1	(QL26D)
LD1-5	Mini LED Red	5	(WL32K)
DD1	DD Display Type A	1	(BY66W)

MISCELLANEOUS

CH1	1A RF Choke	1	(HW04E)
CH2	4m7H Choke	1	(JM95D)
CR1	455kHz Ceramic Resonator	1	(UL61R)
SK1	PCB 2.5mm DC Power Socket	1	(FK06G)
SK2	PCB 5-pin DIN A	1	(YX91Y)
SK3,4,6	PCB Phono Socket	3	(HF99H)
SK5	PCB SCART Socket	1	(FV89W)
PL1	PCB Latch Plug 12-way	1	(YW14Q)
	Co-ax Socket Flush	1	(HH09K)
	DIL Socket 14-pin	2	(BL18U)
	DIL Socket 16-pin	1	(BL19V)
	DIL Socket 40-pin	1	(HQ38R)
S1,2,8-12	Latchswitch 2-pole	7	(FH67X)
	Latchbracket Single	2	(FH75S)
	Latchbracket 6-way	1	(FH80B)
	Rct Latchbutton White	1	(FH64U)
	Rct Latchbutton Red	1	(FH63T)
	Rct Latchbutton Grey	5	(FH62S)
S3-7	Click Switch	5	(FF87U)
	Click Cap White	5	(FF94C)
FS1	Fuse 20mm 1A	2	(WR03D)
	Safuseholder 20	1	(RX96E)
	Display Filter Red	1	(FR34M)
	Ribbon Cable 10-way	1 Mtr	(XR06G)
	Cable Twin	1 Mtr	(XR21X)
	NICAM Tuner Socket PCB	1	(GE38R)
	NICAM Tuner Switch PCB	1	(GE36P)
	NICAM Tuner Display PCB	1	(GE37S)
	NICAM Tuner Case	1	(XM81C)
	Stick-on Feet Square	1 Pkt	(FD75S)
	Display PCB Support Bracket	1	(JR72P)
	Isobolt M3×6mm	2 Pkts	(BF51F)
	Isobolt M3×10mm	1 Pkt	(HY30H)
	Isonut M3	2 Pkts	(BF58N)
	Spacer M3×⅛in	1 Pkt	(FG32K)
	Bolt 6BA×3/16in	4 Pkts	(JR71N)
	6BA Washer	4 Pkts	(BF22Y)
	Spacer 6BA×¼in	2 Pkts	(FD10L)
	Constructors Guide	1	(XH79L)

OPTIONAL (not in kit)

	Mains Adaptor DC 12V 600mA	1	(YZ21X)
	NICAM Tuner Kit	1	(LP09K)
	NICAM Decoder Kit	1	(LP02C)

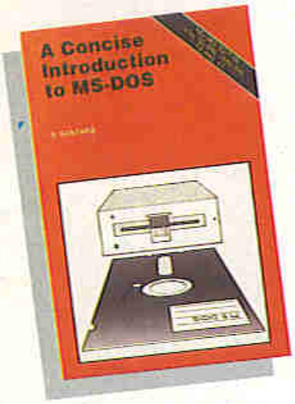
The above items, excluding Optional, are avaliable as a kit:
Order As LP18U (NICAM Accessory Kit) Price £69.95

The following items are also available separately:

Switch PCB **Order As GE36P Price £8.45**
Display PCB **Order As GE37S Price £10.95**
Socket PCB **Order As GE38R Price £3.25**
NICAM Case **Order As XM81C Price £19.95**
10 Pk Bolt 6BA×3/16in **Order As JR71N Price 24p**
NICAM Bracket **Order As JR72P Price £2.45**
M491BB1 **Order As UL60Q Price £9.45**
455kHz Resonator **Order As UL61R Price 68p**
4m7H Choke **Order As JM95D Price 60p**

Now available; the Decoder kit, the TV Tuner kit and the Accessory kit shown here, together in one super kit at an astonishing price:
Order As LP19V (NICAM Tuner System) Price £139.95

NEW BOOKS

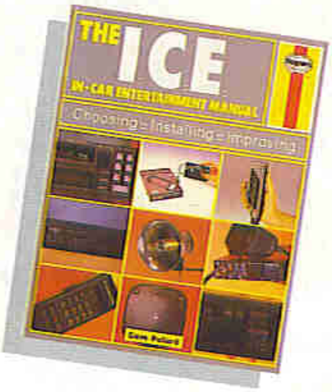


A Concise Introduction to MS-DOS

by N. Kantaris

All PC users who want to get the best out of their computer in terms of efficiency and productivity must learn its PC/MS-DOS operating system. This book will help you to do just that in the shortest and most effective way.
Written with the busy 'non-expert' in mind, it has an underlying structure based on the idea that the things that you most need to know first are explained first. However you need not start at the beginning and go through to the end if you don't want to, more experienced users can go to any section.
The book provides enlightenment about such things as what happens when the computer is first switched on, and the files it uses as it 'auto-boots' from a system disk, how to use 'EDLIN.COM' to write your own 'CONFIG.SYS' and 'AUTOEXEC.BAT' files (and also what to write!), and how to organise your disk storage using sub-directories. Covers all versions of 3.x of both PC-DOS and MS-DOS as implemented by IBM and other manufacturers of 'compatibles' including Amstrad. The menu driven, graphical interface version 4.0 is also mentioned. Since in reality your DOS manual is little more than a reference manual or memory jogger, this book is essential reading for making sense of the manual and properly managing your system's environment.
1989. 80 pages. 198 x 128mm, illustrated.

Order As WS94C (Cnse Intro MS-DOS) **Price £2.95 NV**

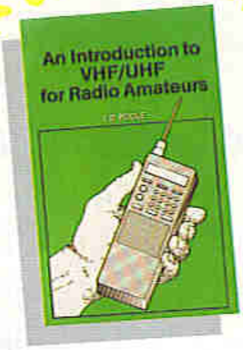


The I.C.E. (In-Car Entertainment) Manual

A 'Haynes' Manual
by Dave Pollard

The I.C.E. (In-Car Entertainment) manual is a complete Do-It-Yourselfer's guide to choosing and installing all types of audio entertainment and communication equipment. A great many drivers will already have some form of I.C.E. equipment but may wish to improve the quality or range of facilities, for example progressing from a simple mono radio to a stereo cassette/radio or CD player, or adding a graphic equaliser or 'sub-woofer' speakers to the latter type of system.
The CB enthusiast is also well catered for, with detailed advice provided for choosing the most suitable 'rig' together with full installation instructions.
Valuable information is also provided for fitting mobile 'phone or TV, and goes so far as to include caravans. Contents include a glossary of terms relating to I.C.E., how to plan, prepare and put together a system, getting together proper tools, connectors, wire and fuses, types of electrical connection, choosing and fitting a radio/cassette, graphic equaliser, power amplifier. Choosing best types of cassettes to use (not as obvious as you might think), and proper care and storage of them, including cassette repairs. How to select and fit a CB radio, and security of equipment. An appendix provides a list of useful names and addresses.
1989. 168 pages. 276 x 214mm hard-cover, illustrated.

Order As WS96E (The ICE Manual) **Price £10.95 NV**

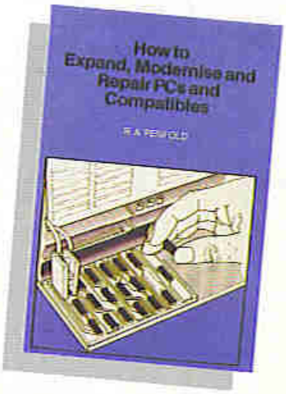


An Introduction to VHF/UHF for Radio Amateurs

by I.D. Poole

The increase in the use of the VHF and UHF bands is now one of the largest growth areas within amateur radio. In fact, most radio amateurs have equipment for use on these bands, either for local contacts or simply to exploit some of the many interesting and challenging aspects of so doing. This book covers the essentials required to gain the most from using the VHF and UHF bands. As such it will be of use to both the newcomer and the more experienced enthusiast alike. Topics include propagation, the bands and channels, aerials, receivers, transmitters, and a special chapter on scanners. In addition, operation of repeaters and mobiles is included together with DXing and data modes, and a section on packet radio.
1990. 110 pages. 178 x 111mm, illustrated.

Order As WS93B (Intro VHF/UHF Radio) **Price £3.50 NV**

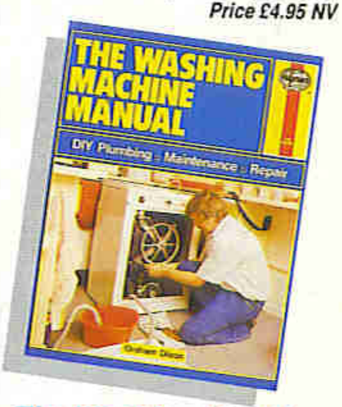


How to Expand, Modify and Repair PC's and Compatibles

by R.A. Penfold

Not only are PC's and compatibles very expandable, but before long many users actually wish to take advantage of that expandability and upgrade their PC systems. Some aspects of this can be a bit confusing, but this book provides advice and guidance on the popular forms of internal PC expansion, and should help to make things reasonably straightforward and painless, and little knowledge of computing or computer hardware is assumed. All you need is to have and be able to operate a PC of some description. Topics include a PC overview, memory upgrades, how to add a hard drive, how to add an extra floppy drive, display adaptors and monitors, fitting a maths co-processor, keyboards, ports, mice and digitisers. All are covered in detail with emphasis on practical advice rather than theory. The final two chapters deal with maintenance (including the preventive kind) and repairs and the increasingly popular subject of DIY PC's.
1990. 176 pages. 198 x 130mm, illustrated.

Order As WS95D (Mod & Repair PCs) **Price £4.95 NV**



The Washing Machine Manual

A 'Haynes' Manual
by Graham Dixon

The householder's complete DIY guide to plumbing-in, maintaining and repairing of automatic, front-loading washing machines, including the latest type of washer/dryer 'laundry centres'. All popular makes and models spanning at least a decade are covered. In the Haynes tradition detailed step-by-step instructions are linked to photographs and fault finding flow charts, enabling the do-it-yourselfer to diagnose and repair faults quickly, saving money on call-out charges and maintenance contracts. Models covered include those manufactured by AEG, Ariston, Balay, Bauknecht, Beekay, Bendix, Blomburg, Bosch, Burco, Candy, Caravelle, Carlton, Creda, De Detrich, Electra, Electrolux, Fagor, Frigidaire, Hirundo, Hoover, Hotpoint, Husqvarna, Indesit, Jackson, Juno, Kelvinator, Kenwood, Miele, Neff, Newpol, Philco, Philips, Prowoda, Samet, Servis, Siemens, Smeg, Zanussi, Zerowatt. Several useful chapters deal with stain removal, the latest information on textile care labelling codes and jargon.
1988. 136 pages. 276 x 214mm hard-cover, illustrated.

Order As WS98G (Wash Machine Manual) **Price £10.95 NV**

COMPUTERS IN THE REAL WORLD

Part 7 by Graham Dixey C.Eng., M.I.E.E.

Magnetic Recording Principles and Methods

The basic principle of recording on the surface of a disk, whether hard or floppy, is similar to that of recording on audio tape. A head, consisting of a small coil on a ferro-magnetic armature, is positioned either in contact with the surface of the medium or very close to it. This head, having a dual role, is termed the read/write head. During the 'write' operation it carries a current (I_w in Figure 1) so as to produce local areas of magnetisation in the surface of the magnetic medium as the latter passes beneath it. These are known as 'bit cells', since each will store one binary digit, or bit, of information. Naturally, with up to eight million such cells on some types of floppy disk, they are rather small in size! During the 'read operation', the head will, by induction, pick up a minute voltage (V_R in Figure 1) from one of these bit cells as it passes over it.

Recording Codes

There are a number of ways of storing binary digits in the bit cells referred to. These are illustrated in Figure 2, to which the following notes refer.

(a) Return to Zero (RZ): A logic 1 is represented by one magnetic state for part of the cell, the rest being returned to zero magnetisation. A logic 0 is represented by 'no magnetisation' throughout the cell. The write head supplies a short current pulse to write a '1'.

(b) Return to Saturation (RS): A logic 1 is represented by one magnetic state for part of the cell, the rest being returned to the opposite magnetic state. A logic 0 is represented by no change from the latter state throughout the cell.

(c) Bipolar Return to Zero (BRZ): A logic 1 is represented by one magnetic state (e.g. a North pole) for part of the cell; a logic 0 is represented by the opposite magnetic state (South pole), also for part of a cell. In both cases, for the rest of the cell the magnetisation is zero.

(d) Non-Return to Zero (NRZ): A logic 1 is represented by one magnetic state, a logic 0 by the other magnetic state. In both cases the whole of the cell is magnetised.

(e) Non-Return to Zero 1 or Non-Return to Zero Invert (NRZI): A logic 1 is represented by a change in the magnetic flux (in either direction) at the beginning of the bit cell, while logic 0 is represented by no change.

(f) Frequency Modulation (FM): At the beginning of every bit cell there is a flux change; for a logic 1 there is also a flux change at the middle of each cell, while for a logic 0 there is no flux change at the middle of the cell. This is the method commonly used for 'single-density' recording.

(g) Modified Frequency Modulation (MFM): The logic 1 and 0 states are defined exactly as for the case of FM. The difference lies in the fact that there is only a flux change at the beginning of a bit cell if both the previous and present bits are logic 0's. This is the method used for 'double density' recording.

(h) Phase Encoding (PE): A logic 1 is represented by a 'change in the flux direction'; a logic 0 is then represented by a change of flux in the opposite direction.

The reader may be interested (and amazed!) to discover that there are several other codes for disk recording, but this review should suffice to give an idea of the various techniques.

Floppy Disks and Floppy Disk Systems

Floppy disks, also known sometimes as 'diskettes', are a convenient mass storage medium for the microcomputer. They are often referred to as 'backing store', meaning that they are additional to the storage provided internally by the RAM area of computer memory. Not only can the user employ floppy disks to store his own programs and data, but much commercial software, including a large amount in the public domain, is available in this medium also. The speed with which this data can be accessed is quite adequate for the majority of applications. The price of disks has reduced substantially during recent years, another factor in their favour.

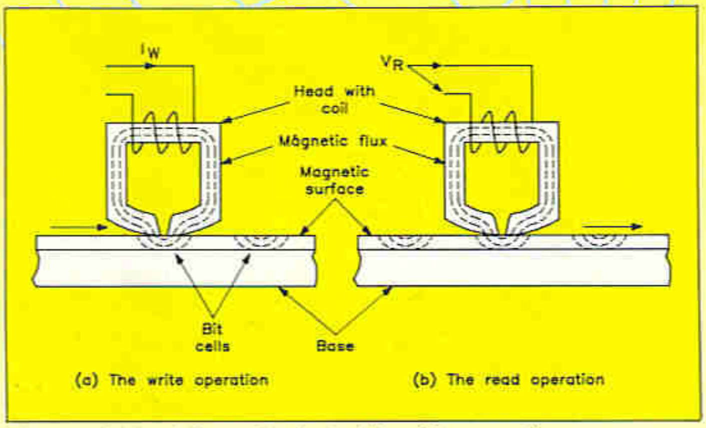


Figure 1. Action of the read/write head in writing or reading data in 'bit cells'.

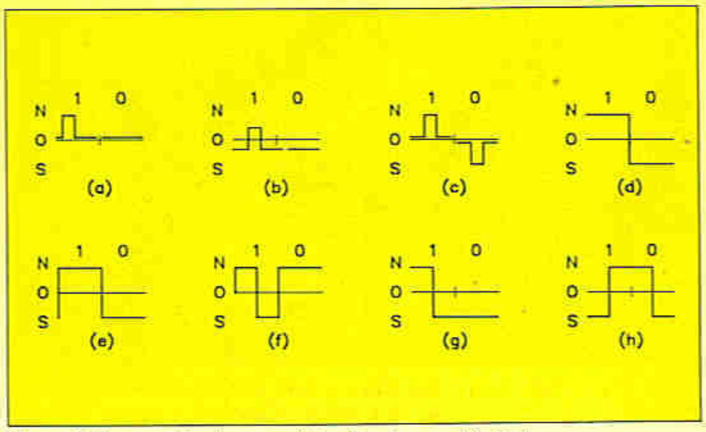


Figure 2. Some of the large variety of codes used in disk recording (see text).

Photo 1. The three current 'standard' disks: left to right, 3½in.; 5¼in. and the less popular 3in.

If there is one problem with floppy disks it is the perennial one of 'standards'. The original floppy disks were quite large, about eight inches in diameter. Following this was the size that itself became virtually a standard, certainly among the smaller users, the 5¼in. standard, an increasingly large number of users now opt for the 'new standard' of 3½in. disks. Indeed, some PC's have both sizes of drive unit fitted so that either disk can be accepted. There are also ways in which data can be transferred between the two standards. The capacity of the 3½in. disk is comparable to that of the larger size, having up to 1 Megabyte of total storage on the two sides. The smaller disk is more robust, being protected in a hard plastic sleeve, unlike the thin card sleeve of the larger disk. The price has also fallen to a comparable level.

Irrespective of the size of disk considered, the principle is the same. The 'disk' itself is made of a thin, flexible plastic, the surface of which is coated with a magnetic material in which the data is recorded by means of a read/write head that bears lightly on the surface. This disk, when it is being accessed in the drive unit, rotates within its protective sleeve at a speed of 300 rev/min. Cut out of this sleeve are two 'windows'. One of these is a radial slot that provides the required access to the magnetic surface for the read/write head; the other is a small index hole which provides a positional reference or datum point. In the case of the 5¼in. disks, these windows are permanently open, hence the need for a paper pocket into which the disk is placed when not in use. In the case of the smaller disks, these windows are protected by spring-loaded metal shutters that open automatically when the disk is placed in the drive. The position of the index hole is identified by an optical device.

In the same way that audio and video cassettes can be protected from 'recording over' by breaking out a tab, the absence or presence of which a sensor in the machine will detect, computer disks can be 'write protected' either by a small patch placed over the write-protect notch at the side of the disk, in the case of 5¼in., or by moving a small plastic slide, that opens or closes a small circular hole, in the case of the smaller disks.

Variations in disks, apart from their size, include whether they are single or double-sided and whether single or double density. The data is recorded in the form of concentric tracks, of which there are usually either 40 or 80. The outermost track is generally called 'track 0'. The two sides of a 5¼in. disk may be accessed by independent heads, so avoiding the necessity for turning the disk over in use. By contrast, drives using the 3in. standard are invariably single-sided, so that to access the alternative side, the disk must be physically removed from the drive, 'flipped' over and re-inserted.

As already stated, the magnetic recording surface is divided into concentric tracks, up to 80. A further division is made, radially into segments, producing sectors which each typically has a storage capacity of either 256 or 512 bytes. Each of these sectors is identified by address information stored at their intersections. This sub-division of the surface into small, individual storage areas has no physical reality. It exists only because of the magnetic pattern 'imprinted' on the disk surface by a process known as 'formatting'. A new disk has to be put through this process before being used for the first time. Thus, when it is then put into service, the magnetic pattern is recognised and the allotted positions of the sectors identified. This arrangement of tracks and sectors is illustrated in Figure 3.

A 5¼in. disk, formatted for 80 tracks per side, has a track packing density of 96 tracks per inch (96 T.P.I.). Thus, only the outer area of the disk is actually used for the recording of data, otherwise the sectors near the centre of the disk would become unreasonably small and cramped. The two sides of a disk may be known as sides 0 and 1. Consecutively numbering *all* tracks on both sides of the disk would give the following arrangement.

On side 0: tracks 0 (outermost) to 79 (innermost).

On side 1: tracks 80 (innermost) to 159 (outermost).

A 5¼in. disk will be formatted to have either 40 or 80 tracks per side with 10 sectors per track. Assume that each sector holds 256 bytes of data so that, with an 80 track, single-density recording, the total capacity will be: 256 x 80 x 10 x 2 = 400K-bytes. Using double-density recording the capacity becomes 800K-bytes, naturally.

Files and Directories

Programs and data stored on disks are held in blocks whose size, in K-bytes, depends upon the size of the program or data file. Each block has its own unique track/sector start address and a 'filename'. The latter is usually restricted to a

Photo 2. The shutter of the 3in. disk has been partially operated to show the disk access slot partly open; the actual disk surface is clearly seen. At the bottom is the index hole, just opening. The small hole (arrowed) top left is the write protect hole.

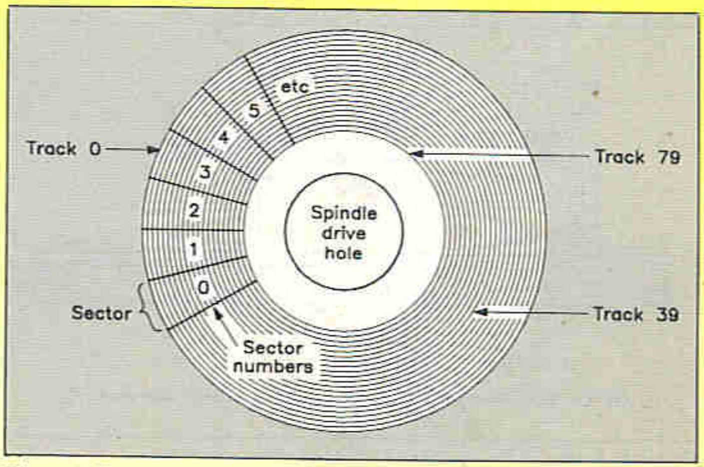


Figure 3. Typical arrangement of tracks and sectors on a formatted disk.

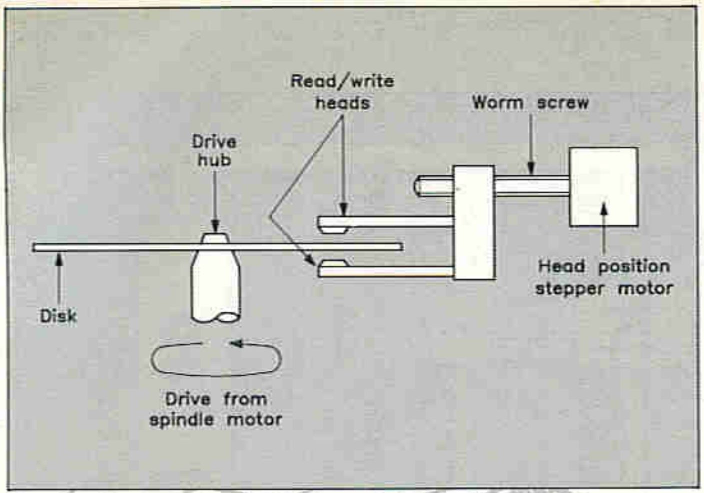


Figure 4. Simple mechanical concept of a floppy disk drive unit.

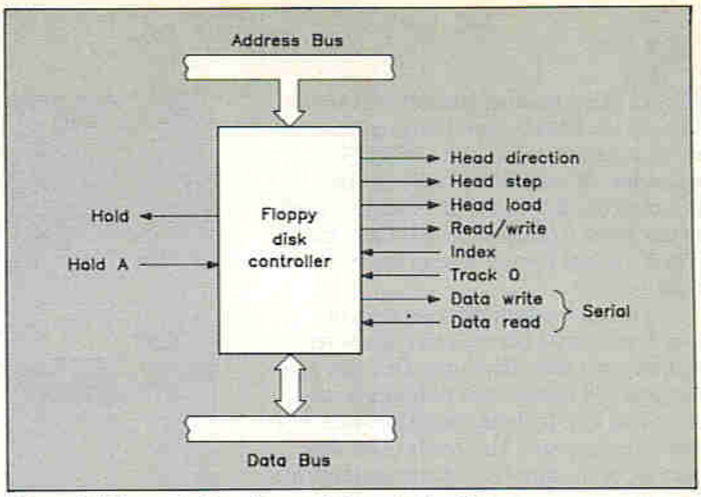


Figure 5. Schematic for a floppy disk controller IC.

maximum of eight alpha-numeric characters. The term 'file' is, thus, quite general for any recorded block of data, regardless of its nature or function. To keep track of the names and locations, a directory is created on the disk, usually in the outermost tracks. This directory has a limited capacity, thus restricting the number of files that can be held on disk, regardless of the capacity of the disk or the size of the individual files.

When a READ operation is initiated for a specified file, the directory is first searched for a file of that name. If no such file exists in the directory an error message is displayed. If the file does exist, then the location and number of sectors comprising the file are read from the information held in the directory and the transfer begins.

When a WRITE operation takes place, the new file is recorded at the next free sector onwards, and its name and other details are written into the directory. In the event that a file of that name already exists, the original file may be modified to include a '.BAK' suffix to the end of its file name, and in this original form will still exist while the new version is added to the disk.

The operation of deliberately erasing a file, say by issuing the ERA command, does not actually affect the recorded data at all. It merely erases the entry for that file in the directory, so allowing further files to over-write the original file space. Only then is the original data lost. The use of a disk editor, after erasing a file but prior to actually over-writing it, will allow the file to be recovered by replacing the directory entry.

The Floppy Disk Drive Unit

The drive houses both the mechanical functions and the electronics required to rotate the disk and access the data via the movable read/write head. The head assembly moves radially across the disk surface, actuated by a head positioning worm screw arrangement, endless loop belt or some such that is driven by a stepper motor. In this way the head is accurately positioned above the required track, while the sectors are identified, as the disk rotates, by their positions relative to the index hole mentioned previously. The position of the latter is sensed optically by a photo-cell. The basic form of a floppy disk drive unit is shown in Figure 4.

The drive electronics must perform a number of tasks.

(a) Move the head to the required track.

(b) Load the head and set up for either reading or writing.

(c) Generate or recognise various control signals, such as those that identify Track 0 and the location of the index hole.

(d) Drive the spindle motor at an accurate rotational speed.

During a data transfer there are three identifiable operations, namely:

(a) Head positioning.

(b) Read/write control.

(c) The actual data transfer.

As already stated the head is positioned by a stepper motor. This type of motor moves in specific increments of 'so many degrees' for each applied pulse. The program that controls this motor must, therefore, generate a specific number of pulses in order to cause the stepper motor to rotate through a particular angle. The positioning mechanism converts this rotation into the required linear movement of the head across the tracks of the disk to the one that has been selected. The head is then 'loaded' onto the disk, that is it is lowered onto its surface. Once loaded, the track number is read to verify position, by comparison with the track register.

Reference to the other two operations will be made later.

The Disk Drive Interface

Interfacing a microprocessor to a disk drive unit is performed by means of a dedicated control IC and interface unit. A typical floppy disk controller IC is shown in Figure 5.

Software sends to the controller IC the required track and sector address. The IC then sets the Head Direction and Head Step signals so as to position the read/write head correctly. The pulse generated by the index hole, referred to previously, is used to determine the correct angular excitation and, hence, the required sector. When the head is correctly positioned at the required sector/track address, the Head Load signal is 'set' and the head is then lowered onto the disk surface. The Read/Write signal determines the direction of data transfer. Data is, of course, written to, or read from, the disk in serial form, bit by bit. Another of the functions of the controller

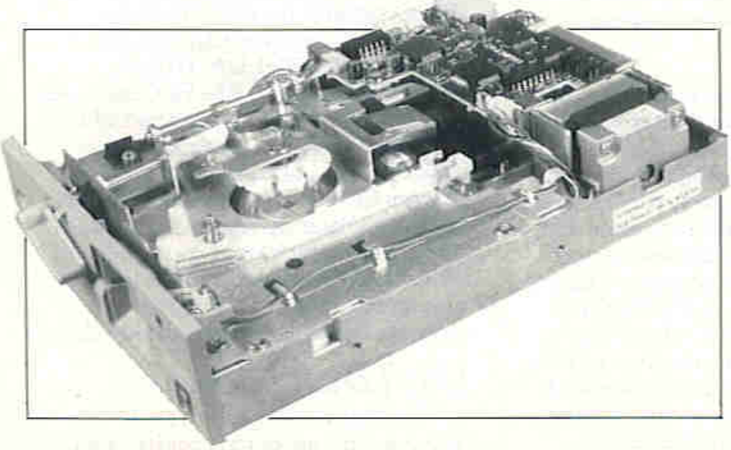


Photo 3. A 5¼in. disk drive unit with the cover removed.

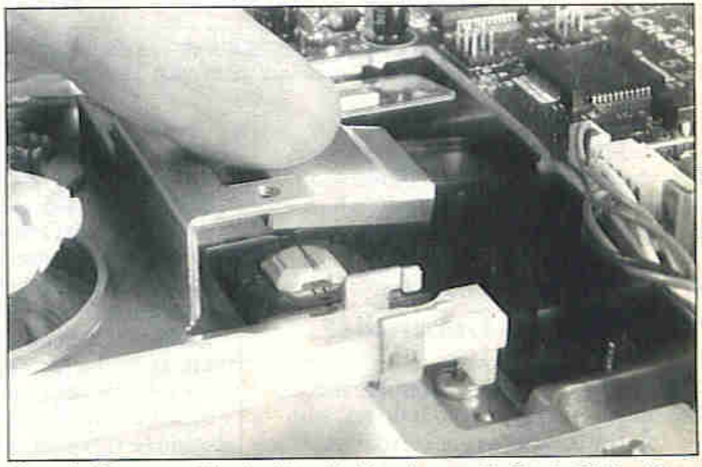


Photo 4. Close-up of the double-sided head assembly for the 5¼in. drive lower head surface is clearly seen. The detail of the unit.

IC is to perform serial-parallel conversion (during the READ operation) and parallel-serial conversion during the WRITE operation. When the disk drive is first switched on, the read/write head sets itself to the Track 0 position; at this time, the Track 0 signal is used to reset the IC's track register.

There are essentially two ways of transferring data between the computer memory and disk drive unit. One way is to use normal input/output techniques, the transfers, byte by byte, being handled by a software program. This tends to be slow because of the numbers of instructions that have to be executed during transfers of substantial amounts of data.

The favoured method, that avoids the above disadvantages, is known as Direct Memory Access (DMA). In this method, the transfer of a specified block of data is initiated by software but a hardware device, called a Floppy Disk Controller (FDC) IC, takes over. This handles the transfer itself without any further software intervention. Figure 6 illustrates the basic idea behind the DMA method, showing how the CPU is bypassed during transfers.

The FDC provides the necessary interface between the CPU and the disk drive, converting the software commands issued by the Disk Operating System (DOS) into the electrical signals needed to control the drive. Special purpose IC's, such as Intel's 8272 exist for this purpose. It is possible to have what is known as an 'intelligent floppy disk interface', which has its own on-board CPU, such as a Z80.

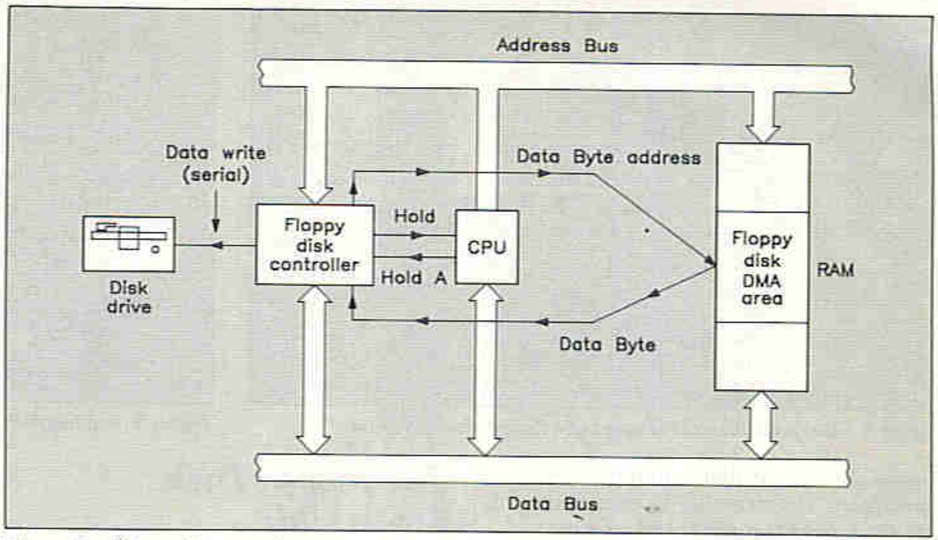


Figure 6. A Direct Memory Access (DMA) system in use, showing how the CPU is effectively bypassed.

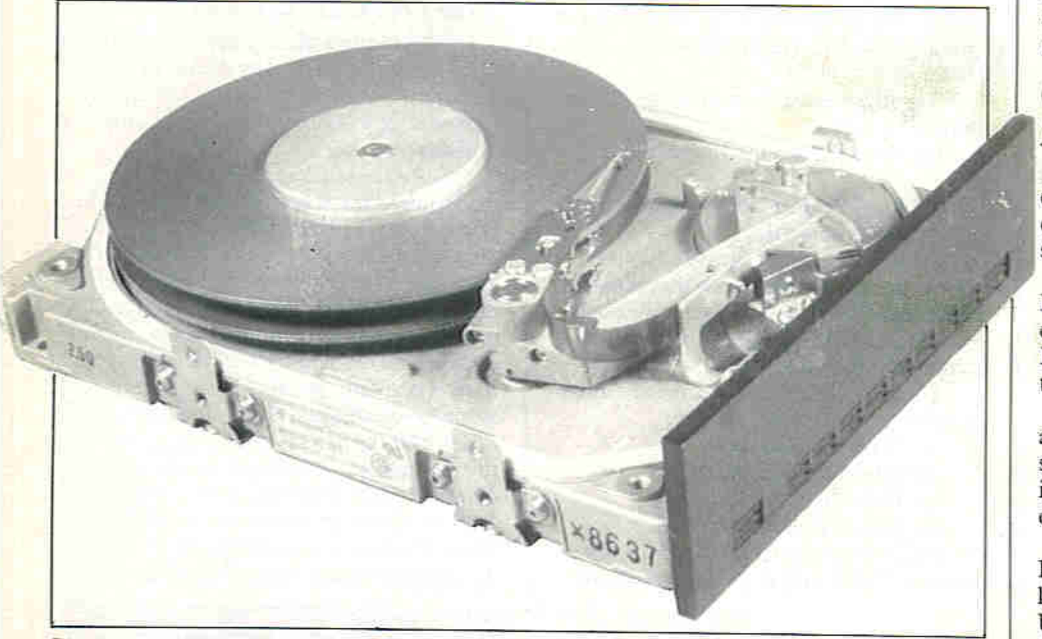


Photo 5. A Seagate Technology 20M-byte hard disk unit with sealed case removed. Only two double-sided platters with one head per surface are needed. Disk size is 5¼in.

Basic Functions of a Floppy Disk Controller

These are as follows:

(a) Select drive: one controller may look after a maximum of four drives, with the ability to select any one on receipt of the appropriate command.

(b) Seek track: a sequence of step pulses moves the read/write head to the required track, in a particular direction. If moving outwards, the Track 0 signal is used to terminate the movement when this track is reached.

(c) Read/Write: the controller 'loads' the head onto the disk surface, allows a 'settling time' before the transfer commences and generates a signal to select either the read or write mode.

(d) Data separation: as recorded, the data to/from disk is a serial bit stream of mixed data and clock pulses. The actual data must be separated from the clock pulses and then converted to parallel form.

(e) Error detection: in any serial data path, such as that between memory and disk drive, there is always the possibility of data being 'corrupted', that is individual bits inverting their binary values. Clearly the received data will then be incorrect but unless this fact is detected in some way, it could be accepted as being valid. Writing to disk is normally error checked by reading during the next revolution of the disk. After, say, 10 such attempts have failed to produce valid data, an error message should be displayed that may even identify the faulty sector.

Errors may be caused by electrical noise that, if temporary, will eventually allow a successful transfer; this is known as a 'soft' error. Hard errors are usually permanent and may be caused by physical contamination of the disk surface. Error checking is usually performed by a sophisticated checksum method known as the Cyclic Redundancy Check (CRC).

Operation of the Floppy Disk Controller

Taking the WRITE operation as an example (data being 'written' from computer memory to disk), the role of the software is to:

(a) Supply the floppy disk controller IC with the start address (in an area of the computer RAM memory known as the DMA area) of the data block to be transferred.

(b) Supply the corresponding start address on the disk where the data is to be stored; this takes the form of track/sector information. Also required is the number of sectors needed for the storage.

On receipt of this information, the FDC IC takes over. Its first function is to locate the specified track/sector address. Upon doing so, it generates and sends a HOLD signal to the CPU. The latter completes its current instruction and responds with a HOLDA (HOLD Acknowledge) signal. The FDC takes over direct control of both the data and address buses and carries out the data transfer. Unlike the normal input/output transfers between CPU and peripherals, which use the Accumulator (A-register) as a 'transit area' for the input/output ports, the CPU is completely bypassed in DMA transfers. This speeds up the transfer rate enormously, for the reasons already stated.

Hard Disk Systems

Hard disks, also known as 'Winchesters', are of rigid construction, hence the name. The disks are usually made from aluminium, coated with a magnetic material such as ferric oxide or chromium oxide. The special aerodynamically shaped head is known as a 'flying head', and fly heights of 0.5-3.0 microns are usual. (A micron is a millionth part of a metre.) The heads can be designed to take off from, and land on the disk surface, this feature being characteristic of Winchester drives. The disk surface is lubricated to minimise the risk of damage. The complete system is hermetically sealed to provide a totally dust free environment.

Unlike the floppy disk, which is only rotated during access times, the hard disk assembly rotates continuously, at a speed of 3600 rev/min. Because of their bulk and consequent inertia, it can take anything up to a minute for hard disks to reach their full operating speed.

Hard disk systems may use either fixed or moving heads. Fixed head disks have one read/write head per track, an extravagance that is compensated for by the much reduced access time and the saving made by not requiring a positional motor drive. A moving head assembly uses one read/write head per disk surface, thus requiring a positional motor for accessing the required track on a surface, in exactly the same manner as for floppy disk systems.

Advantages of hard disks over floppies are:

(a) A much greater storage capacity. A 20M-byte system is now considered quite modest while, for those who can afford them, hard disk units offering 180M-bytes or even 320M-bytes are now available.

(b) A faster access time, by a factor of 10:1, compared with floppy disks.

(c) System software is automatically loaded when the system is switched on, giving immediate access to application software such as word processors, databases, etc.

Naturally, there are different sizes of hard disk, according to capacity, but the user may be less aware of this due to the fact that the hard disk unit is housed within the main computer casing. There is even a 5¼in. standard, which is capable of giving a capacity of up to 40M-bytes of storage. Large capacity Winchesters are of 'multi-platter' construction. The 22M-byte disk assembly shown in Figure 7 has four double-sided platters, thus requiring eight read/write heads altogether. Each platter has 320 tracks per side with 17 sectors per track, each sector having a capacity of 512 bytes. Using this data, the calculation for the total storage capacity is: Total capacity in K-bytes = 8 x 320 x 17 x 0.5 = 21760K-bytes, (512 bytes = 0.5K-bytes), which equals 22M-bytes approximately.

There is a standard connector interface for Winchesters, the details being given in Figure 8.

The next part in this series will attempt to explain the principles of stepper motors, as well as the methods of driving and using them and some of their most useful applications.

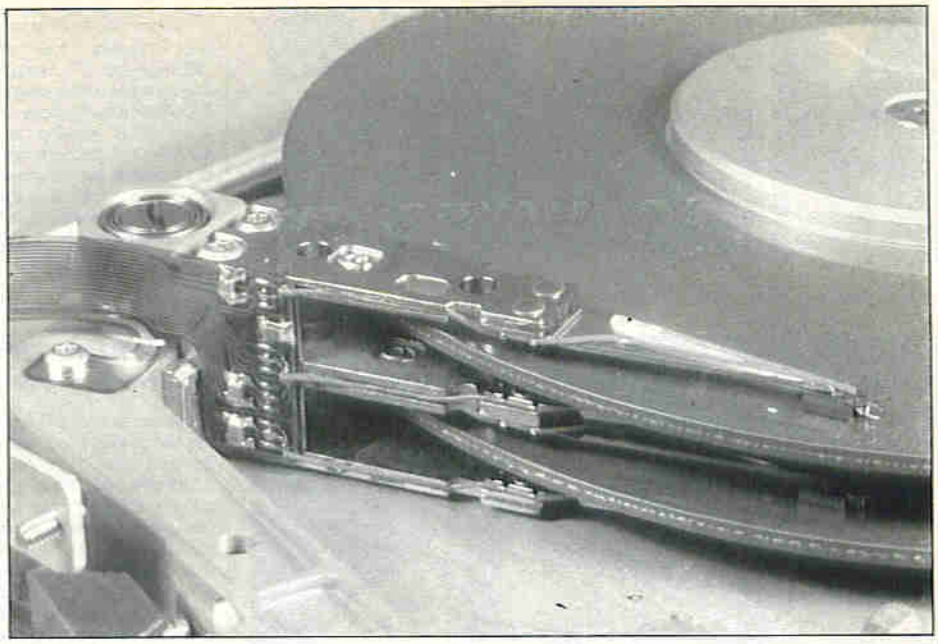


Photo 6. Close-up of the head assembly of the hard disk drive.

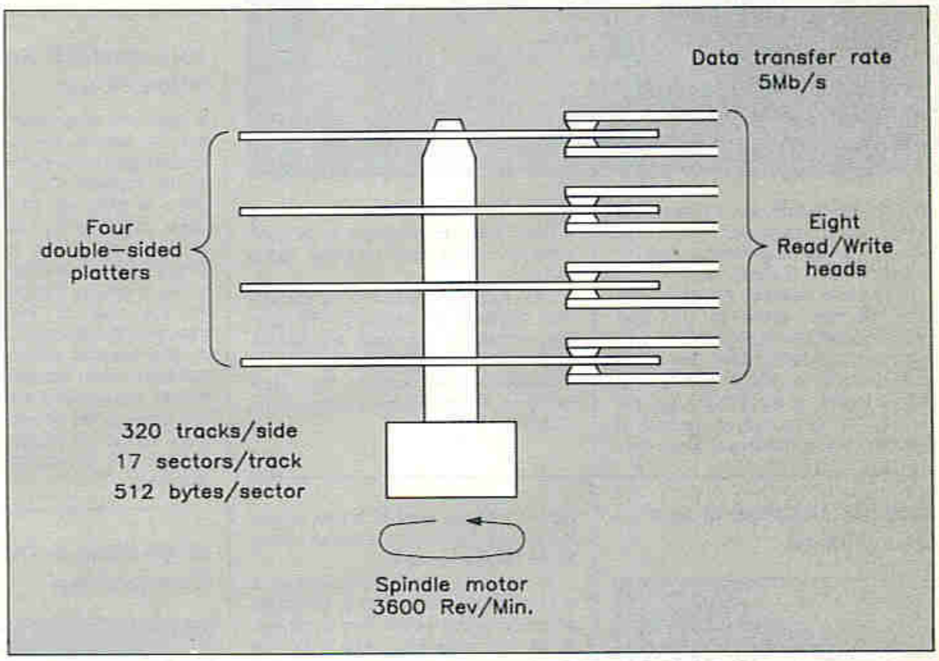


Figure 7. The layout of heads and platter for one form of 22M-byte hard disk drive.

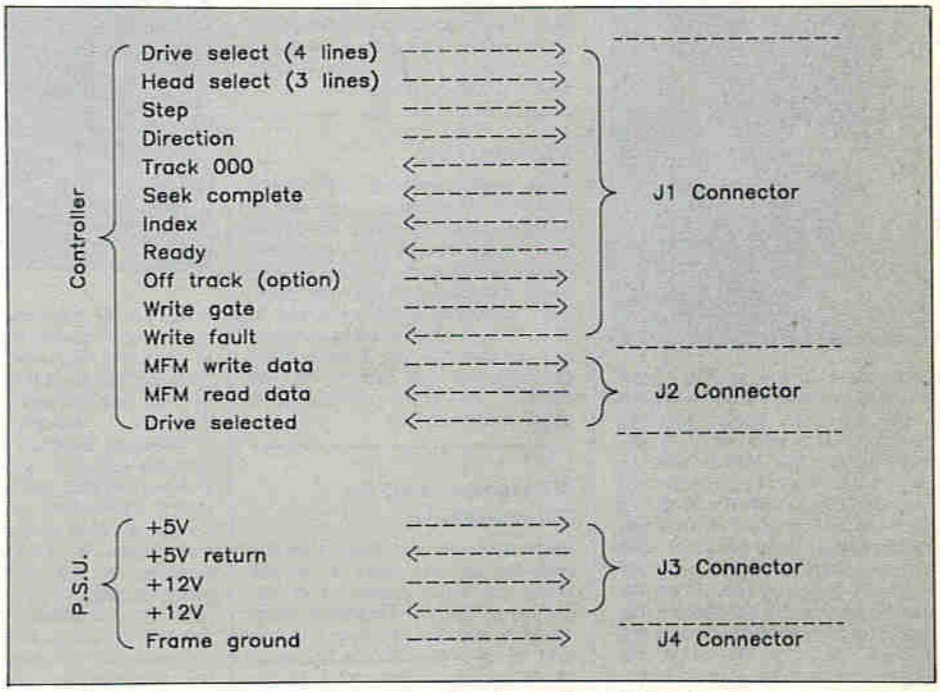
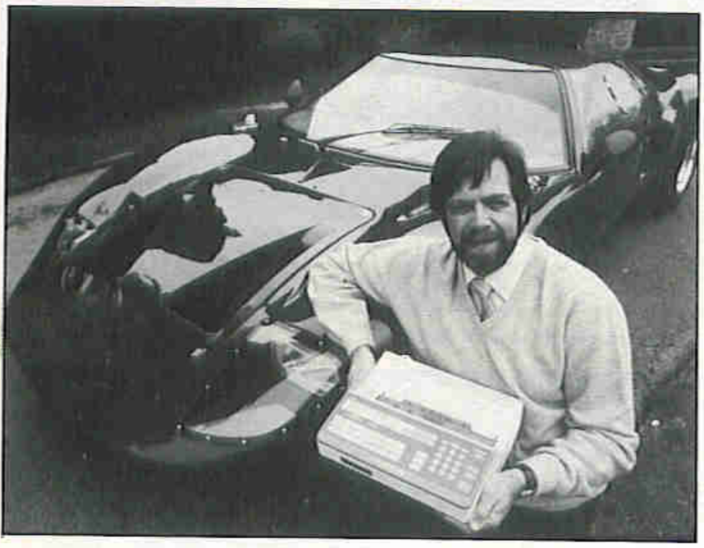


Figure 8. Standard interface connections for a Winchester (hard disk) drive system.

NEWS REPORT

CarFax



What is the connection between the worlds most prestigious sports car race, a small engineering firm in Somerset and a fax machine?

The historic Le Mans 24-hour motor race has seen some of the most exquisite examples of engineering ever to put a wheel on the road. One of the best loved cars, which achieved a string of wins in the 1960s was the Ford GT40. Since only a handful of these incredible machines were ever produced, a thriving industry has built up over the last few years to produce replicas using the original body moulds.

One such constructor is the specialised engineering company "The Garage" located in Somerset. And the fax connection? Well, 'The Garage' owner received a faxed enquiry from Germany for a Ford replica costing some £40,000.

Hubble Bubble Goes Into Space

The success of the Hubble Space Telescope is being closely monitored by the European Space Tribology Laboratory. The solar array 'wings' which provide the Hubble with its power, are displayed by a complex set of mechanisms, described by NASA as a technological miracle. The 12 tonne, railway-carriage sized telescope was lifted from Cape Canaveral on board the NASA Space Shuttle Discovery back in April. One day into space it was lifted out of the hold by robotic arm and released. The huge 5kW solar rays (wings) which provide electricity from sunlight were then deployed from either side of the telescope body. This means that the Hubble is now a free flying, self-powered spacecraft ready for its 15 year mission.

The Hubble Space Telescope is a 2.4 metre diameter reflecting telescope of extraordinary power and accuracy. In its 350 mile orbit, free from the distortion of the earth's atmosphere, it will allow astronomers to see further into the universe and therefore further back in time, to around 15 billion years, which cosmologists believe will reveal the origins of the Big Bang. Details: AEA Technology 0925-31244.

Windy City

More down-to-earth is the £240m European Wind-tunnel being built in Cologne, West Germany. The tunnel will provide aircraft and equipment designers with more accurate aerodynamic test data than currently available. Scheduled to be completed in 1992, the unit which is a joint cooperation between the UK, France, West Germany and the Netherlands, will simulate the entire cruising-speed range of civil aircraft.

Getting a Job In Electronics

Chartered electronic and electrical engineers are very much in the fast ahead job lane. According to the Institute of Electrical Engineers, salaries have risen by 10% over the past year to give an average salary of £25,000. Best pay bets are in broadcasting, telecommunications and the armed forces.

Meanwhile, the Department of Trade and Industry has announced a "Women into IT" campaign, aimed at encouraging more women to develop information technology skills. The government is making available some £500,000 of public funds to the cause but whether the funds will go towards bolstering the average salary of women in electronics which is some £8,000 less than their male colleagues, is not revealed. Details: DTI 071-215-5000.

Don't Blame Us – Blame the Computer

It just had to happen! A student living in the Isle of Wight has received a poll tax demand for – wait for it – £3,864,081:55. When queried, a computer produced note suggested that the amount should be paid in monthly instalments.

A computer error was also blamed after a chap waiting for a bus in Maidstone was handed a poll tax demand by a passing postman. It was addressed to "The Occupier, Bus Stop, High Street".

Sky and BT Score in World Cup

In case you have been in orbit for the past six weeks, the world has been focussing its undivided attention on the World Football Cup contest taking place in Italy. All 52 matches have been screened by Sky's Eurosport channel and if that is not enough, British Telecom International operated a free of charge access (you only pay for the cost of the call) to an international database "Italia 90", giving pre and post match coverage. The database menu includes matches and results, players and managers, stadia and cities, goals scored, plus a World Cup history of facts and records. Details: BTI 071-492-2626, Sky 071-782-3000.

High Power Desktop Computing

Described by the company as "the world's most powerful desktop personal computer", the recently announced Compaq Deskpro 486/25 is based on the new Intel 486 microprocessor and Extended Industry Standard Architecture. Designed for advanced, computer-intensive applications, the Compaq 486/25 delivers 15 MIPS (million instructions per second) of computing power up to three times the performance of 25MHz 386-based systems. In applications such as computer-aided design, software engineering, database management, financial modelling, or for networking and multi-user configurations, the system is described as delivering workstation power to the desktop PC environment with full compatibility with industry standards. The suggested resale price is £10,495. Details: 081-332-3000.

Post Office Set to Stamp on British Telecom

The review of the British Telecom/Mercury duopoly in UK telecommunications gets under way in November – some seven years after Mercury got its licence. It is expected says Dr Paul Matthewson of telecoms consultancy Applied Network Research, that the government will extend the number of licenses and at the same time, allow BT to carry TV signals over its network. In fact the lobbying has already started with the Post Office, British Rail, Racal and the US company Sprint being likely contenders.

Whether the UK can in fact support a third or even fourth national telephone company is of course a debatable point. But as Paul comments, "Mercury has not made a dramatic competitive impact except perhaps for large City of London users. Further licensing could well serve to dilute the national competition even further".

Already moving along IT lines is British Rail Telecoms whose 10,000 mile telecoms network which runs alongside its tracks, is seen as making the organisation a front runner. Also a front runner as consultancy PA point out, is the Post Office which has set up a new company called National Network. Initially the company will be selling spare capacity on its private telecom network which currently has 25,000 users operating out of 200 locations and an annual capacity for 12M telephone calls. Not surprisingly the contending services are being tagged in the industry as "Post-IT" and "Missed-IT".

Don't Phone Home

Meanwhile, Chris Buckley of The PA Consultancy has produced figures which highlight the seemingly random method which BT adopts over its UK phone charges. If you live in London, and make a call to a village in the north of Scotland, the call will cost you 17 pence per minute during a weekday. If you live in Scotland, more than about 35 miles from the same village, the call will cost the same.

BT telephone charging says Chris is based upon charging areas. Only go over two 'charging area boundaries' however at your peril. These are the lines, drawn on the map by BT, and kept secret, that decide which calls are local and which are at higher rates. The strange aspect is that if you are near the edge of a charging area you might find that some calls at 5 pence a minute, go to places further away than some at 12 pence a minute.

International calls are even more illogical. If you call Edinburgh from London, it costs 14 pence a minute during a weekday. A call from London to Calais, however costs 43 pence a minute. Overall Chris believes that BT's UK charges are good value. However medium-distance calls are not so good. The consultancy believes that there are several ways of improving the situation:-

★ Users should be told how calls are charged.

★ Telephone directories should provide more information.

★ The introduction of more competition.

BT Under Fire

As if British Telecom does not have enough problems what with the possibility of further national telephone operators being licensed, the corporation is now under fire over both its international and national telephone charges. Calls for the breaking-up of the 'international phone cartel' have surfaced after a report in the Financial Times that BT has a profit margin of nearly 60% on international calls.

Now the UK telecoms regulatory quango, OFTEL has woken up and commenced an investigation into the matter. The authority admits that in most cases, international calls are significantly above cost and that it is all too easy for telephone operators to make a high level of profits. However, more positive help for the public is promised by The Commission of The European Community, who noting the OFTEL report, is launching its own investigation of alleged profiteering by the international telephone authorities. Commission vice-president Sir Leon Brittan has commented that the Commission has to ensure that consumers benefit from an international telephone charging system which allows genuine competition between the telecommunication operators.

Meanwhile, independent management consultancy Sterlings of North London point out that nearly ⅔ of all UK phone users believe they have been overcharged in the past twelve months. As a TMA survey confirms, the average BT subscriber has been overcharged more than 13 times in the past year and even Mercury subscribers report being overcharged once or twice.

BT Reverses the Charges

British Telecoms response to these claims was predictably robust. The claims that its charges are amongst the highest in the world is nonsense. A true comparison needs to look at the overall 'basket' of charges and typical usage. On that basis, BT charges fall about mid-way in an international league table.

But just in case the charge is proven and BT have to reduce tariffs, the corporation has reduced the eight days a year when special concessionary day rates apply to just three, concentrated exclusively over the Christmas and New Year period.

Computers get on their Knees

Again it just had to happen. A UK company, Limwood Technology for Mission Ltd., has developed a range of ecclesiastical software. Apart from a database of sermons, the package will suggest suitable seasonable hymns and maintain stock control. No mention of robotic clergy, yet.

Thanks for the Memory

Panasonic have developed a range of credit-card sized memory cards which offer high-speed access, resistance to static electricity, mechanical strength, low power consumption and long-life memory back-up. Memory cards have a wide range of applications in the area of office automation, sales automation, communications, factory automation, electrical appliances, health monitoring and educational equipment from storing word-processed text to medical records.

The Panasonic memory cards incorporate full 25kV electrostatic protection which prevents the memory from being damaged by the harmful effects of static. The insertion/withdrawal lifetime is rated at 10,000 times while high performance poly-carbon monofluride Lithium batteries and low back-up power consumption, give an estimated ten years of use at normal temperatures. Details: 0344-853259.

Getting the Message

Voice messaging, one of the fastest growing areas of communications has been given a major boost by Millicom Cellular (UK). Operating on both the Cellnet and Vodafone networks, Callbank is a new personalised cellular answering and messaging service which allows incoming calls being diverted to another telephone number when required. Details: 071-757-5000.

Get Me Bucharest

Judging by recent figures, companies such as Millicom are on to a good thing. According to figures compiled by consultancy Applied Network Research the European telephone market is set to grow by nearly 40% per annum for the next five years – equivalent to some 34m units. While ANR expect the overall value of sales in the UK to decline, the emerging Eastern European market, such as Romania, will show a dramatic leap. Not surprisingly major consultancies such as ANR, PA and Andersen are already establishing contacts behind what was until a few months ago, the iron curtain.

Just how long it will be before the Eastern European users will be complaining about their new telephone services remains to be seen. But apparently 90% of UK companies are suffering from inefficient telephone systems. According to a Datapulse Survey, average callers will wait just 35 seconds before hanging-up, while one in 15 calls are lost while being routed to an extension. No doubt the likes of Philips, one of the UK's major switchboard equipment suppliers, will be loosing little time getting in touch with the management of those troubled company exchanges.

Satellite Wars

No issue of "News Report" would be complete without an update on satellite TV. Already Sky, the European operator, is claiming over 500,000 subscribers for its Sky Movie Channel – a total only held back apparently by the outstanding delivery time-scales of systems and decoders.

British Satellite Broadcasting, the 'authorised' UK TV channel operator, finally got its service off the ground in May, with five programme channels: Movies; Sports; Entertainment; Current Affairs and The Power Station dedicated to young viewers. Worth watching out for is the BSB 'Computer Channel', a weekly IT current affairs programme which is being masterminded by ex-editor of 'Which Computer?' Clive Couldwell.

BSB conversion equipment prices range from £350 to £390 to buy or typically £12.99 per month to rent a satellite antenna, set-top receiver box and remote control. As is the situation with Sky, there is also a subscription charge for the Movie channel.

The Sky ASTRA satellite system has of course, the advantage of carrying not just 4 UK-based channels, but a host of European channels, plus Sky Radio – a 24-hour non-stop stereo popular music station which is broadcast on a Sky One sub-carrier.

Sky Goes Green

A transparent glass satellite dish designed to overcome environmental objections to unsightly metal and fibreglass alternatives, has been developed for Sky by electronics company Zeta Services. It is made from Armourplate metal impregnated glass that has the same reflective qualities to microwaves as standard metal dishes.

Sky is also bringing environmental comfort to apartment blocks with a single communual antenna which can be used to relay satellite channels around an entire block or housing estate.

Meanwhile, recognising the growth in demand for satellite broadcasting, the DTI is bidding for a further 5 channels for Direct Broadcasting by Satellite (the system used by BSB) to the UK.

Trusting Times

Good news for the Maplin sales team, is the industry report forecasting that the sale of test equipment is set to jump by 71% over the next couple of years. A Frost and Sullivan Report points out that the radio and TV industries will remain the largest consumer of EMI/MFI test equipment and facilities, closely followed by telecomms and the automobile industries.

Meanwhile, testing, or rather the lack of it would seem to be the root cause for the Japanese Ministry of International Trade and Industry to issue warning notes to its manufacturers. Apparently so many functions are being packed into laptop computers and television sets that they are suffering from smoking, or even small fires. The Ministry is calling for tighter safety and quality control. Or possibly to incorporate small smoke detectors in their equipment.

Cray Sets a Fast Pace

Whether smoke detectors were triggered is not revealed but in a recent industry speed challenge, Cray Research has been named as manufacturer of the world's fastest computer. The Cray performed some 3,500 times faster than the industry benchmark, the DEC Vax 11/780, beating the competition from Hitachi, NEC and Fujitsu in total execution.

Meanwhile, the DEC PDP-11 minicomputer, the forerunner of the Vax computer, is celebrating its twentieth birthday. The PDP-11 which defined the minicomputer market, became irrevocably linked with OEMs and brought computers and computing closer to a generation of users, university students, scientists and technicians. There are now approximately 600,000 PDP-11s in the market and the family, says DEC will continue to evolve to meet existing user demand. Details: 0734-868711.

Picture Caption

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

★ An adult Lego set.

★ A mad cow detector.

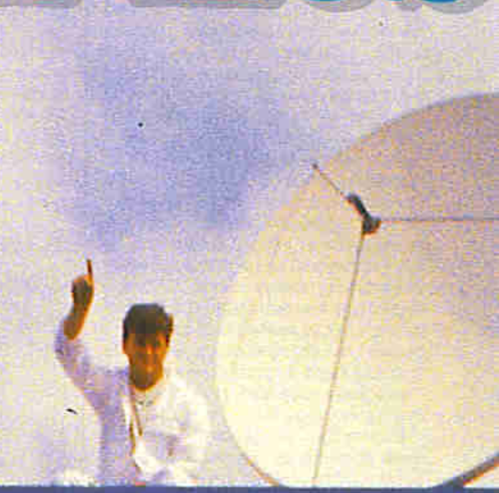
★ Another fiendish challenge for contenders of Channel 4 series, 'The Crystal Maze'.

or even

★ A satellite TV viewer installing a filmnet decoder; "No one told me that unscrambling the new Sky TV movie channel would be so difficult!"

Well, actually it is a scientist at the AT&T Bell Laboratories adjusting a component in the world's first digital optical processor. The optical processor, which makes use of light (photons), as opposed to electrons, to process information, may eventually enable computers to operate 1,000 times faster than their electronic counterparts today.

Sky Flies



If you really want to step into the office of the future, then a visit to the new SKY TV offices close by London's Heathrow airport would be well worthwhile. Here every desk not only has a computer terminal, but is within zapping distance of wall to wall TV screens. SKY TV, owned by News International of Rupert Murdoch fame, opened for business last year, comfortably beating by twelve months the rival BSB operation.

Sky has already recruited over one thousand staff whose role, says Fiona Waters, Director of Press and Publicity, is to handle programme production, engineering, scheduling, advertising sales and marketing, press and publicity and administration. And that number excludes the growing army handling subscriptions based up in Scotland plus of course, the numerous independent production teams and performers who are sub-contracted. Sky produces a wide range of children's programmes, magazine shows, news features and sports programming in-house as well as commissioning work from an extensive range of British Independent Production Companies.

Sky broadcast four programme channels; SKY ONE, the entertainment channel; SKY NEWS, the 24-hour news channel; SKY MOVIES, the pay-TV film channel; and EUROSPORT, which will be screening live, all 64 rounds of the World Cup football competition in Italy. Then almost as a bonus, the station broadcasts SKY RADIO, a 24-hour non-stop stereo, classic and contemporary hits, music station. Using the SKY ONE subcarrier, the service is available to all home aerial dish owners. Teletext has not been overlooked and SKY TELETEXT can be received across all four TV channels.

Getting the Message

SKY TV programmes are sent by land-line direct from SKY's office or contractors studios direct to BTI's uplink satellite ground-station in East London for onward transmission to the Astra satellite hovering some 22,300 miles above the Earth. The signals are then beamed down to your receiving antenna (dish), all in the space of a second. All SKY transmissions are in the PAL-D format used by the existing terrestrial BBC, ITV and Channel 4 services. But the traditional single sound channel technology has been improved to provide for multiple sound channels allowing for example, Eurosport to broadcast simultaneously in English, German and Dutch.

But SKY viewers also get a further major bonus. Their satellite carrier Astra, beams down no less than 16 channels, most of which are in English and perhaps more to the financial point, free. SKY channels apart, Astra broadcasts a WH Smith 'Lifestyle' channel, a Childrens Channel owned by BT, Thames and Central Independent TV, and MUSIC TV (MTV), modestly described as being the world's premier 24-hour youth entertainment channel. As MTV's Debbie Woodcock says, "we broadcast from our North-London studios, all contemporary musical tastes from Hip-Hop to Heavy Metal".

Still uncertain about taking the Astra plunge? Well scheduled to be fully operational next year, Astra 2 will provide even more viewing choice including three British-owned stations. So, who says we don't want more TV channels? Certainly not the 5.2m plus regular Sky viewers in some 1.5m homes in the UK and Eire. As Fiona points out, Pan-European Sky Euros-

OUT AND ABOUT

High

by Alan Simpson

Sky News engineering crew. ▶

Sky staff in front of the Sky HQ.▼

port Channel broadcasts to 20m homes in 22 countries. Even the Sky Movie channel (£10 per month) has 712,000 paying customers so far.

Star Wars

Just in case you are wondering where the alternative satellite channel run by British Satellite Broadcasting fits in, the answer must be uneasily. Not only are they competing with the vigorous Sky TV organisation with largely the same base of programmes, but with an incompatible satellite carrier. BSB who were awarded the monopoly access to the more powerful Direct Broadcasting System, uses the Marcopolo I satellite.

The rivalry between Sky and BSB is for real. BSB even tried to have the law amended to preclude media owners from operating a TV station. However Marcopolo does carry the new BSB subsidiary DataVision service which transmits data and graphics traffic within the UK.

Satellite TV for the uninitiated is about as different as is The Miss Saigon musical from The Sound of Music. No longer is news, music, movies or entertainment limited to thirty minute quota slots per week. They are there as and when you feel like it.

It's a Scramble

As Fiona makes clear, the aim of scrambling is to ensure that only fully paid-up subscribers can watch the pay-only Movie channel. The Sky Videocrypt system has been developed in-house and features a decoder which plugs into the satellite receiver, and a smart card which slots into the decoder. A new smart card encoded with different security algorithms is sent to subscribers every few months to ensure that pirating is both difficult and economically unviable.

The Videocrypt system relies on a video line rotation method for scrambling the signal and for subscriber access, the smart card actuates the decoder to reassemble the video for authorised viewers. The audio signal is left 'clear' (i.e. unscrambled) intentionally. Successive video lines are cut

Inside the MTV control room.

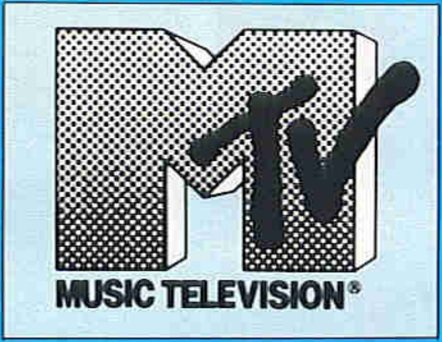
MTV technician at work.

at randomly selected points and transposed.

The key to the scrambling sequence and other control data is transmitted during the vertical blanking interval of the scrambled television signal and received by the subscribers' decoder. The microprocessor in the smart card employs public key cryptography to continuously prove its authority to access pay television channels. Having established its authority, the smart card employs a second security algorithm instructing the decoder about rearrangement of the scrambled video signal.

Sky Goes Green

The latest Astra receiving dish features a see-through perforated construction, which says Fiona, will make the dish almost invisible. Highly efficient, the glass-based dish will be far less obtrusive than even conventional TV aerials. In contrast, BSB make use of a Squarial, or small parabolic dishes. All satellite systems need a receiver box which serves to decode the satellite signal into high quality sound and pictures for your TV set.



MTV logo.

The cost of setting up a SKY satellite system is about £200 for the basic dish and receiver (£250 for remote control) plus the installation costs which are normally under £80. Or there is a special SKY package of £23.50 a month which includes satellite dish, receiver and remote control, decoder (for Sky Movies), installation, maintenance and the film premium subscription.

Until now, TV development has been a long-drawn out affair. BBC 1 went live back in 1945 and was joined ten years later by ITV. A further ten year period saw BBC2 arriving on the screen followed twenty years later by Channel 4. However, the next ten years saw much progress and now we have some 17 UK-based terrestrial and satellite channels available in the UK. With Sky forecasting over fifty available TV channels by 1992/1993 and nine million subscribers by the end of the decade for the Astra satellites alone, perhaps it is just as well that those dishes are going green.

MTV 'ident'.

Win a SKY TV Satellite System!

This month, the Maplin 'Win a ... Competition' is really flying high. Just answer correctly the four questions and the first name drawn out of the editor's hat (I don't wear a hat! - Ed.), wins a ready-to-view SKY satellite system. This includes Amstrad black mesh 60cm Astra satellite dish and integrated receiver/Sky decoder. The mesh dish is 'environmentally friendly' (you won't fall out with the neighbours) and the decoder for the SKY MOVIES channel is built into the satellite receiver as one compact unit. The prize includes installation (value £329 for dish, plus approximately £60 installation). Subscription to Movie Channel is not included. The first runner-up prize is a behind the scenes tour for two of SKY's Headquarters in Isleworth, Middlesex. And for the second runner-up, a tour for two of the MTV 24-hour pop music station in North London and a chance to meet a pop celebrity. So don't delay. Closing date is 31st October 1990.

Post your entry to SKY TV CONTEST, The Editor, 'ELECTRONICS – THE MAPLIN MAGAZINE' P.O. Box 3, Rayleigh, Essex, SS6 8LR. Or zapp your entry by FAX on (0702) 553935, don't forget to mark the fax SKY TV CONTEST.

SKY© TV CONTEST

1 Norman Tebbit is a regular SKY TV current affairs commentator. He is perhaps best known as:

(a) A member of The Stranglers pop group.
(b) An advisor to the Poll Tax protest movement.
(c) An advisor to the unemployed on cycling.
(d) A world aerobic champion.

2 Which artist would you not normally expect to be specially featured on MTV – Europe's only 24-hour stereo music channel?

(a) Madonna.
(b) Michael Jackson.
(c) The Rolling Stones.
(d) Gracie Fields.

3 The ASTRA satellite was blasted into space by which rocket?

(a) Ariane.
(b) Sputnik IV.
(c) The Cape Canaveral.
(d) The Eurostat.

4 In the future will SKY TV be regulated by:

(a) OFTEL.
(b) The DTI.
(c) Edwina Currie.
(d) The Independent Television Commission.

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 1

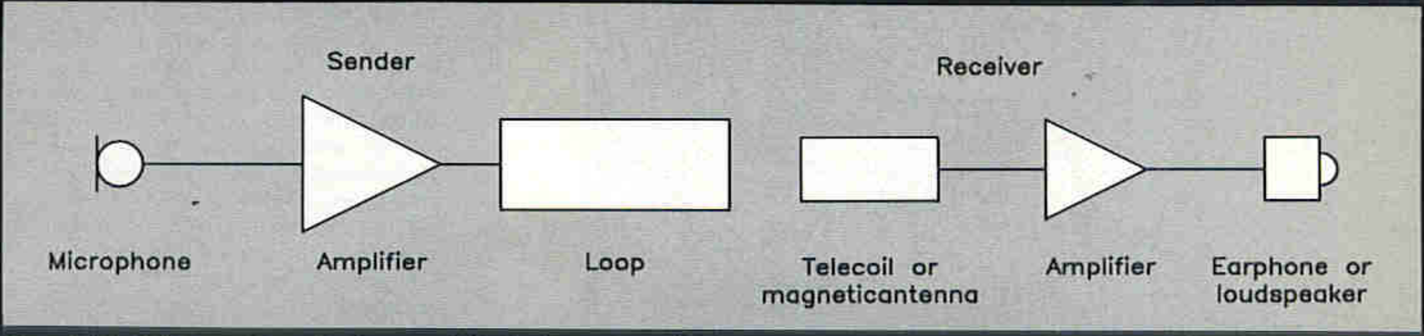


Figure 1. Block diagram of an audio-frequency induction-loop system (AFILS).

Introduction and Design

Audio-frequency induction loop systems (AFILS) have been used for many years as a way of improving communication with hearing-aid users, and are increasingly being used for other purposes, with staff in shops, etc. They are interesting in several respects, not the least of which is that they demonstrate immediate practical applications for some 'standard results' from school physics (teachers please note).

Inaccurate and Unreliable

Unfortunately, a great deal of inaccurate material about loop systems has appeared in print, so one of the objects of this series of articles is to demonstrate the correct theory and design procedures. In addition, details of a loop-system amplifier, suitable for home use, or in a small office or committee-room, will be given, together with designs for a receiver for a loop communication system, and a low-cost field-strength meter for measuring the performance of a system.

Another widespread problem has been that generally loop systems have been very unreliable (as any hearing-aid user frequenting theatres will testify). This is being remedied by the preparation, under the aegis of the *British Standards Institution*, of a 'Code of Practice', which not only deals with design methods but also installation, maintenance, provision of information (signs for the hearing-aid users and operator's guides for staff) and the training of staff, together with recommendations for correct use of the system to ensure the safety of the public. Most of this is concerned with AFILS in public buildings, of course, but parts of it are applicable to household and office systems as well. It will soon be necessary, also, for loop systems above a certain size to be certified as not being likely to cause electromagnetic interference, by complying with a specification, not yet finalised, to be issued by the Department of Trade and Industry. This is unlikely to affect small household systems unless interference actually occurs, for instance, the author recently found a small system which was oscillating at 5MHz, for example!

What is an AFILS?

An audio-frequency induction-loop system consists of four parts (Figure 1). First comes a source of audio signals, which is usually a microphone. Second is an amplifier, which causes an audio-frequency current to flow in the third item, a loop (or loops), of wire. The fourth item is a receiver, which is sensitive to the magnetic field produced by the current flowing in the loop (Figure 2), and which produces a sound output which the user

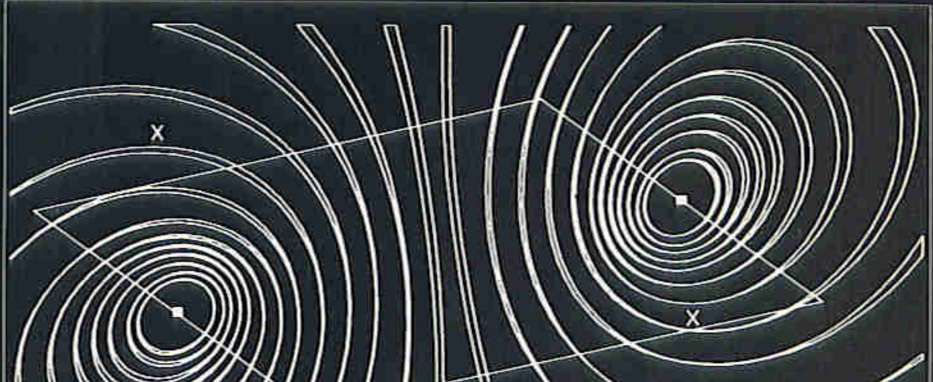


Figure 2. Pictorial view of the magnetic field ('lines of force') in a plane through one axis of a rectangular loop. NOTES: A. In the plane of the loop the direction of the field is perpendicular to the plane. B. In the blank areas surrounding each conductor, the lines of force continue to crowd together, representing a stronger field. C. At certain points (such as X, X), above and below each conductor, the direction of the field is parallel to the plane of the loop. Normally, at these points, a hearing aid produces no output. For normal listening heights, the points are outside the perimeter of the loop.

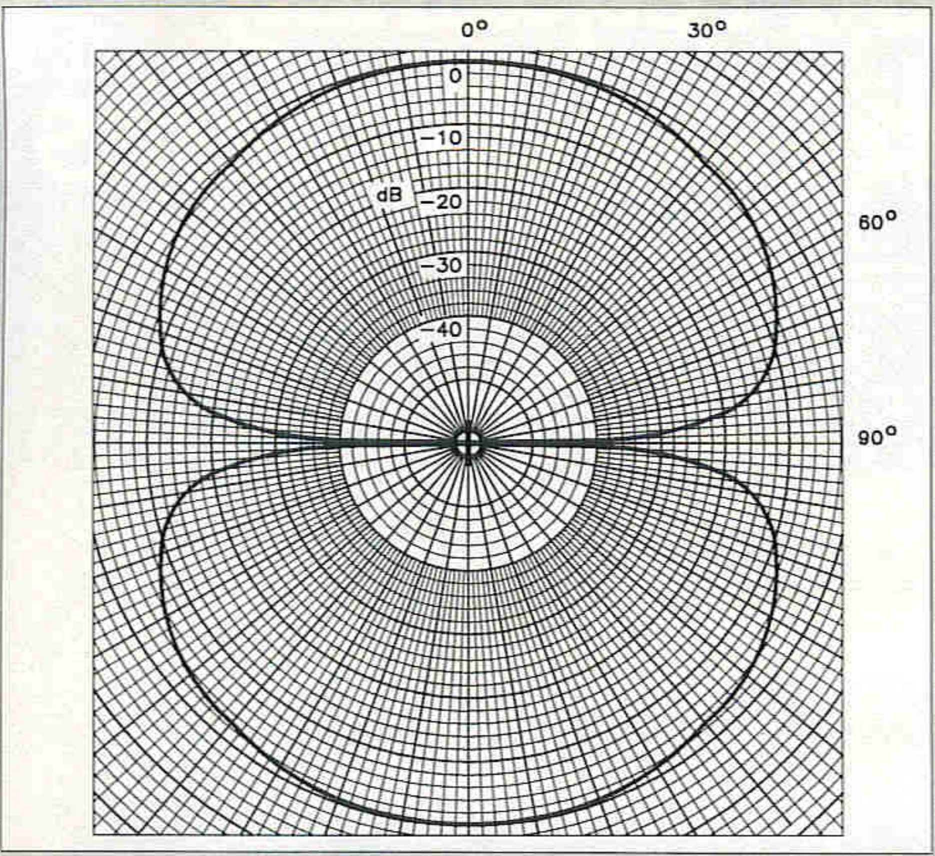


Figure 3a. Directional response of a hearing aid telecoil, plotted on a linear amplitude axis.

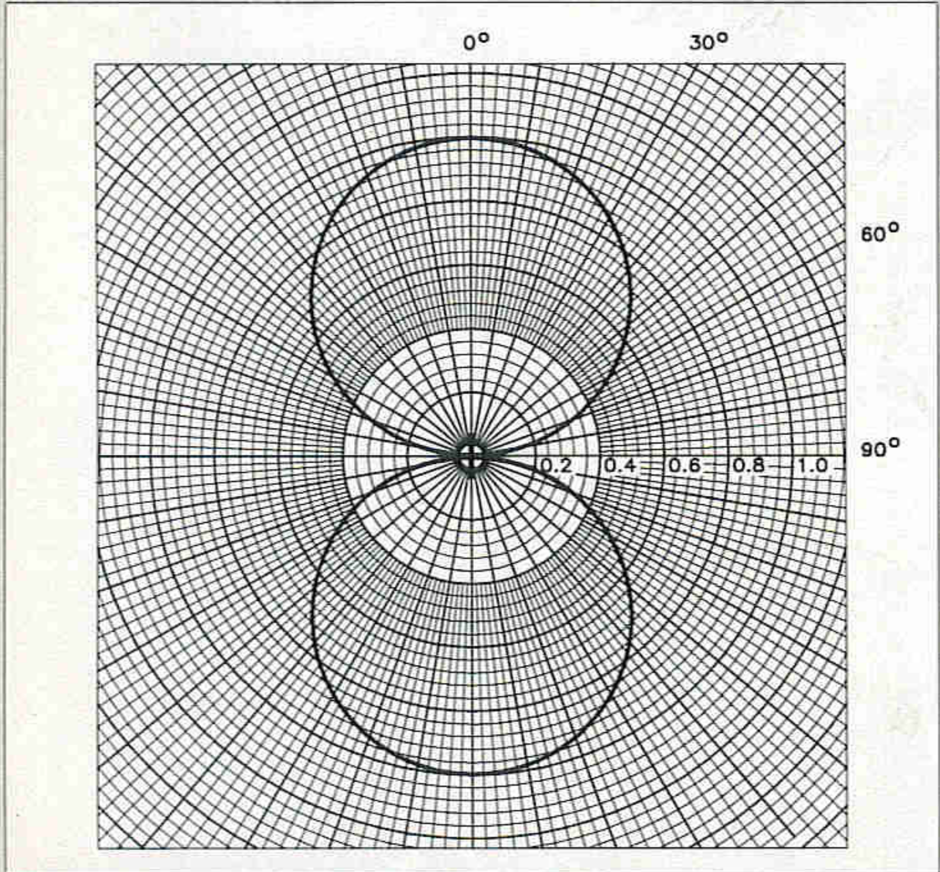


Figure 3b. Directional response of a hearing aid telecoil, plotted with amplitude in decibels (logarithmic axis).

can hear. In 'AFILS for assisted hearing', the receiver is a hearing aid. Although some aids have no facility for use with an AFILS, most of them are fitted with a 'telecoil', several thousand turns of extremely fine wire wound on a tiny rod of high-permeability alloy. The magnetic field produced by the loop induces a small voltage in the coil, which is amplified and fed to the earpiece of the aid. The hearing aid has a switch, marked 'M – T' (or 'M – MT – T'), which selects the input either from the microphone in the aid or from the telecoil, (or both, if 'MT' is provided). This facility was originally intended to help with the use of the telephone: the coil picks up the magnetic field produced by the telephone earpiece, or even the 'induction coil' of old-style telephones. Some modern telephones do not produce enough (or any) magnetic field, and special versions of these have to be made for use by people with impaired hearing. In other applications of AFILS, where the receiver need not be so small, a much less expensive 'magnetic antenna', consisting of a few turns of wire forming a coil a few centimetres square, can be used.

The loop itself exists in two basic forms. In 'ticket office systems' (which are also used in such places as banks and post offices), the loop consists of one or more coils of wire, arranged so as to give a predominantly vertical magnetic field in the region of the ticket window. For example, a horizontal coil may be placed under the counter on the customer's side. The field has to be more or less vertical because the coil in the hearing aid is more or less vertical (depending on the shape and stance of the user). However, the loss due to the directional response characteristic of the telecoil is only 3dB at 45° (Figure 3), so exact alignment is unnecessary.

The other sort of loop is intended to produce a magnetic field that can be picked up anywhere in a room. A cable may be run around the room at ceiling height, above the ceiling or on or below the floor. If the ceiling is very high, the cable may be installed at a lower level. Except in certain special cases which will be explained, such a loop should consist of *one turn*.

Overspill

If the loop runs around the walls of the room, its magnetic field extends well outside the room, which may be an advantage in a house (Grandpa can still hear the television while he is in the kitchen), but a disadvantage in a block of committee rooms, or a home for elderly people, where people in adjacent rooms should not be able to receive the signals. It is not possible to remove this 'overspill' entirely, but it can be greatly reduced by several means. The simplest technique is to install the loop under the floor covering or on the ceiling, and make it as small as will give the necessary coverage in the room. For example, no-one is likely to listen with the hearing-aid next to the wall, so the loop need be no closer than 1m or so to the wall. In a typical room, this leads to a loop 2m x 3m. Directly above the loop wire, the magnetic field direction is horizontal, so that a normal hearing aid registers a null, but even a small movement either way restores a usable signal level, and in practice the null seems to be hardly noticed. There are more complex methods of reducing overspill: one is to use two groups of small loops, one

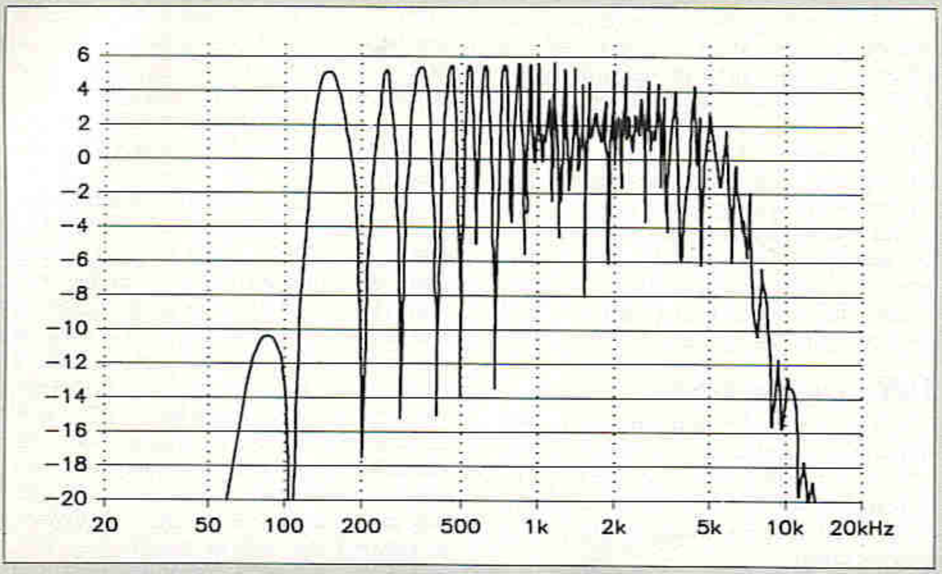


Figure 4. Example of the 'comb filtered' frequency response given by an AFILS with overspill reduction achieved by using two loops fed by equal currents with 10ms time-delay between them. The effect of comb-filtering with such closely-spaced null's is nearly inaudible. The apparent unevenness in the pattern above 1kHz is due to aliasing between the frequency sweep rate and the rate of change of response, in spite of the use of a slow sweep speed.

group being fed with a signal delayed by 10ms or so. It can be shown that this technique reduces the field strength outside the area of the loops, with a null every 100Hz (Figure 4). You would imagine that this would be absolutely unusable, but in fact the effect of this sort of filtering is nearly inaudible!

The Loop Field

It is the current 'I' in the loop which produces the magnetic field. The field strength H_o at the centre of the loop is important in design. For a (single-turn) circular loop of radius 'r', the relation is fairly well-known:

$H_o = I/2r$.

If I is in amps and r is in metres, H is in amps per metre, which we now have to write 'Am^{-1}'.

The equation for a rectangular loop 'a x b' is less familiar:

$H_o = 2I\sqrt{(a^2 + b^2)}/\pi ab$.

We can simplify this a bit by noting that $\sqrt{(a^2 + b^2)}$, is the length of the diagona of the rectangle, and we can calculate it once and call it 'd', so that $H_o = 2Id/\pi ab$. For much of the work, we can deal with square loops, where b = a and d = $a\sqrt{2}$, giving $H_o = 2\sqrt{2}I/\pi a$.

In the plane of the loop, the field strength varies greatly over the area of the loop, rising to very large values indeed near the wire (Figure 5). We are interested in the vertical component of the field, and this rises to peaks just inside and just outside the loop, being zero exactly at the wire. The horizontal component is huge at the wire and zero in the centre of the loop. Luckily, if we put the wire at floor or ceiling level, the hearing aid is in a plane, the listening plane, which is on average about 1.2m away from the plane of the loop. There are four cases to consider, the behind-the-ear or body-worn aid, and the user standing or sitting. (If the user is lying down, the telecoil axis is normally nearly horizontal and the aid responds to the horizontal component of the field.) This separation smooths out the variation of field strength over the loop area, and it can be neglected for small household systems. However, an increase in loop current is necessary to produce the required field strength.

The field strength actually required is basically established by an international standard, IEC118-4, of which the British version is BS6083-4. This stipulates a time-averaged field strength of $0.1Am^{-1}$ at the centre of the listening plane, and a permitted variation of ±3dB over the coverage area (which extends outside the projection of the loop on to the listening plane because of overspill). It also allows a variation with frequency of ±3dB between 100Hz and 5kHz, relative to the value at 1kHz. This is all very well as far as it goes, but it does not go far enough. It draws attention to the fact that signal peaks must produce much stronger fields than the average, but expresses this as a capability for producing $0.4Am^{-1}$ averaged over 0.125s, a type of measurement which is highly unusual. It does not give any requirements for distortion, nor for signal-to-noise ratio. Published scientific papers are of little help in settling the two latter questions, but practical experience indicates that 5% total harmonic distortion (of low order) is the maximum tolerable, as is a signal-to-noise ratio of 26dB A-weighted *measured at the output of a hearing aid (or equivalent).*

The problem of measuring the levels of programme signals is complex, but the people who have been forced to produce a workable solution are the broadcasters, so that they do not over-modulate their transmitters. They have developed the Peak Programme Meter (PPM), two versions of which are standardised in IEC268-10 (BS5428-9, to be replaced by BS6840-10). This meter has a defined attack-time, so that it does not respond to very short transients which may be clipped without audible effect, and a slow fall-time, so that the operator can see the effect of peaks without being driven crazy by a

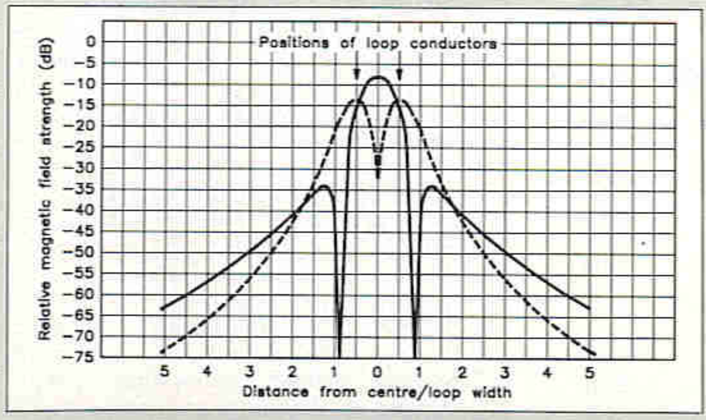


Figure 5a. Variation across the *median* of a square loop of the perpendicular (full line) and co-planar (dotted line) components of the magnetic field at a normalised listening height h_n = 1. ($h_n = 2z/a$, z = distance between loop and listening planes.) The direction of the co-planar component is along the median, and the field strengths are referred to the field strength at the centre of the loop and in its plane as 0dB.

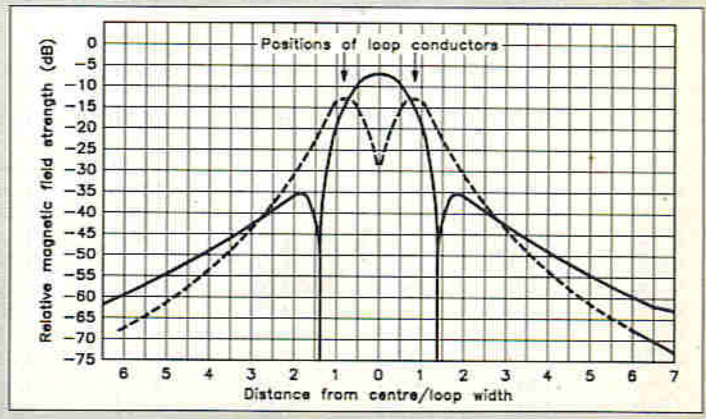


Figure 5b. Variation across the *diagonal* of a square loop of the perpendicular (full line) and co-planar (dotted line) components of the magnetic field at a normalised listening height h_n = 1 ($h_n = 2z/a$). The direction of the co-planar component is along the diagonal, and the field strengths are referred to the field strength at the centre of the loop and in its plane as 0dB.

pointer jumping all over the scale. There is still a problem in translating an average level into a PPM level, but, in the present case, equating a 0.125s average field strength of $0.4Am^{-1}$ to a PPM level corresponding to $0.56A^{-1}$ is sufficiently accurate. It is important to establish this maximum required value of field strength, because it determines the amplifier output specification. Note that the ratio of these values is *not* the ratio of peak to r.m.s.: the PPM is itself calibrated in r.m.s. values and the ratio in fact represents the 'smoothing' action of the averaging process.

The standard value of magnetic field strength was established more than 10 years ago, and was to a significant extent a compromise between the achievement of a good signal-to-noise ratio in public buildings, especially theatres, where there are often interfering magnetic fields produced by fluorescent lighting, lift motors etc., and the avoidance of strong fields, including overspill, which could cause interference with telephone and other equipment, and annoyance to passing hearing-aid users. Recent work reported in technical papers by a number of scientists and engineers has shown that, provided magnetic interference is not a problem, as is usually true for household systems, the average field strength can be reduced by 3 to 5dB, under which conditions the hearing-aid user often does not need to adjust the gain control of the hearing aid when switching from normal conversational use ('M' position) to AFILS use ('T' or 'MT' position), which is very convenient for the user. This reduction can be quite important in the design of the system, as it considerably reduces the requirements for the amplifier. For what follows, I shall assume a reduction of 4dB, so that the average field strength is $63mAm^{-1}$, and the maximum is $350mAm^{-1}$.

Driving the Loop

Now that we know the magnetic field strength requirement, we can calculate the current required for any size of loop, by rearranging the appropriate equation for H_o in terms of I. For example, our 2 x 3m loop requires:

$$I = \pi abH_o/2d$$
$$= \pi \times 2 \times 3 \times 0.35/2\sqrt{(2^2+3^2)}$$
$$= 0.91A$$

However, we have to correct for the difference between the field strength at the centre of the loop plane and that at the 1.2m distance of the listening plane from the loop plane. The equation for this correction is very complicated, so I have written a program to calculate values (Table 1), and this gives a correction of approximately 2.5 times, so we end up with a requirement for 2.3A. How many volts must the amplifier produce to push this current round the loop? The answer, of course, is given by the impedance of the loop (V =IZ).

Table of the function $H_o/Hz = \sqrt{((1+g^2)(g^2+gh^2+1)(g+h^2)(1+gh^2)/(g(g^2+2gh^2+1)))}$ from h = 0 to h = 1 for values of g from 1.0 to 6.5. H_o/Hz is equal to the ratio by which the loop current must be increased to compensate for the distance between the loop plane and the listening plane.

	g = 1.000	g = 1.500	g = 2.000	g = 2.500	g = 3.000	g = 3.500
h	H_o/Hz	H_o/Hz	H_o/Hz	H_o/Hz	H_o/Hz	H_o/Hz
0.000	1.000	1.000	1.000	1.000	1.000	1.000
0.100	1.013	1.015	1.019	1.024	1.029	1.034
0.200	1.050	1.059	1.076	1.095	1.115	1.135
0.300	1.114	1.134	1.171	1.213	1.258	1.303
0.400	1.206	1.239	1.304	1.378	1.456	1.536
0.500	1.326	1.377	1.475	1.589	1.709	1.832
0.600	1.477	1.548	1.685	1.846	2.017	2.191
0.700	1.663	1.755	1.937	2.150	2.378	2.613
0.800	1.884	2.001	2.231	2.503	2.795	3.097
0.900	2.145	2.288	2.570	2.906	3.268	3.644
1.000	2.449	2.619	2.958	3.363	3.801	4.256

	g = 4.000	g = 4.500	g = 5.000	g = 5.500	g = 6.000	g = 6.500
h	H_o/Hz	H_o/Hz	H_o/Hz	H_o/Hz	H_o/Hz	H_o/Hz
0.000	1.000	1.000	1.000	1.000	1.000	1.000
0.100	1.039	1.044	1.049	1.054	1.059	1.064
0.200	1.155	1.176	1.196	1.216	1.236	1.256
0.300	1.348	1.394	1.439	1.484	1.530	1.575
0.400	1.616	1.696	1.777	1.857	1.938	2.018
0.500	1.956	2.081	2.206	2.332	2.457	2.583
0.600	2.369	2.547	2.726	2.906	3.086	3.266
0.700	2.851	3.092	3.334	3.577	3.821	4.065
0.800	3.404	3.715	4.029	4.344	4.660	4.977
0.900	4.028	4.417	4.810	5.205	5.603	6.001
1.000	4.724	5.198	5.678	6.162	6.648	7.136

First calculate $h = 2z/\sqrt{ab}$, where 'z' is the distance between the planes and 'a' and 'b' are the lengths of the sides of the loop. g = b/a, the aspect ratio.

Table 1.

The loop of wire has resistance of course, but unfortunately it also has inductance; it is a single-turn coil. Even more unfortunately, it happens that the inductance is likely to be large enough to matter, unless we are careful: it is liable to raise the impedance sufficiently at high frequencies to prevent the frequency response requirements of BS6083-4 (±3dB from 100Hz to 5kHz) being met. The amplifier, having a flat frequency response, applies the same voltage to the loop at all frequencies, so the current level is reduced by 3dB at the frequency f_o where the resistance and inductive reactance are equal:

$$R = 2\pi f_o L$$

To meet BS6083-4, f_o should be at least 5kHz. In order to prevent possible interference, especially due to harmonics at low r.f. should the amplifier be overloaded at any time, the −3dB frequency should not be significantly above 5kHz, either.

Loop Resistance and Current Ratings

The resistance 'R' depends on the length of wire 'k', the area of the conductor(s) 'A' and the resistivity of the material 'ρ' (Greek letter 'rho'). The basic formula is:

$$R = \rho k/A$$

For copper wire at a slightly above normal ambient temperature (the current heats the wire a bit), ρ = 18nΩm. Wire areas are often specified, but *must* be converted from square millimetres to square *metres* for use in the equation! When they are not specified, they can be calculated. For example, Maplin L/C wire BL46A (black) has 10 strands of 0.1mm copper. Each strand has an area of $\pi \times \{(0.1/2) \times 10^{-3}\}^2 = 7.85 \times 10^{-9}m^2$, so the total area is $7.85 \times 10^{-8}m^2$. Our 2 x 3m loop uses 10m of wire, so the resistance is $18 \times 10^{-9} \times 10/(7.85 \times 10^{-8}) = 2.29\Omega$. Can we put 2.3A through this wire? According to the Catalogue specification, it is rated at 0.5A, so we can't. However, these current ratings for equipment wire are usually based on an ambient temperature of 70°C, and when used as an induction loop the wires are operating at about 20°C ambient. Consequently, they will carry much more current without overheating. Furthermore, the 2.3A is the maximum current, and we know that the *average* current is 5.6 times smaller, i.e. 0.41A, which is within the rating of the wire, anyway. Normally, I would not advise exceeding the published ratings of any sort of component, not even wire, but this is a special case, and I have checked by experiment what happens. To get a worst-case condition, I twisted together two 2m lengths of wire, joined them together at one end and drew the twisted pair into 2m of plastic trunking. I then measured the resistance between the open ends before and immediately after passing 3A through the wire for long enough for the temperature to stabilise. The temperature rise can be calculated from:

$R_t = R_o (1 + \alpha t)$

Where R_t is the resistance at temperature t, R_o is the resistance at the initial temperature and α is the temperature coefficient of the resistivity of copper, 3.93 x 10^{-3} (more school physics!). Rearranging:

$$t = (R_t - R_o)/\alpha R_o$$

To get an accurate value of t, you need very accurate measurements of resistance, because the change in resistance is very small. In the present case, the temperature rise was less than 10K (or 10°C), so the wire was easily coping with 3A.

Inductance of the Loop

You might well wonder why we are bothering to look at passing large currents through thin wires. This becomes somewhat clearer when we look at the inductance of the loop. A number of weird and wonderful formulæ for the inductance of a single rectangular turn appear in books, but for audio frequencies and thin non-magnetic conductors in air the accurate equation is:

$$L = (\mu_o/\pi)\ \{b \ln(2a/d) + a \ln(2b/ø)\}$$

Where μ_o is the permeability of space, $4\pi \times 10^{-7}Hm^{-1}$, a and b are the lengths of the sides and ø (Greek 'phi') is the diameter of the wire, all in metres. ('ln' is the abbreviation for 'natural logarithm', which used to be written '$\log_e$'.) This equation is difficult to handle, but it happens that it can be greatly simplified for AFILS, where a and b are very much larger than ø. Firstly, calculation shows that the inductance hardly varies with the ratio b/a (the 'aspect ratio' of the rectangle, for which the symbol γ, Greek 'gamma', is used) over the practical range from γ = 1/12 to γ = 12, and if we put b = a:

$$L = 2a\ (\mu_o/\pi) \ln(2a/ø)$$

Secondly, for the loop and wire sizes used in AFILS, ln(2a/ø) is always very nearly 10, so, substituting numerical values:

$$L = 8 \times 10^{-6}a$$

Or, even more simply, the inductance in microhenries is equal to twice the perimeter of the loop in metres. Quite a simplification!

Using this equation, the inductance of our 2 x 3m loop is 20μH, which has an impedance of 0.63Ω at 5kHz. This is very comfortably below the resistance of the loop, 2.29Ω as we saw above, but that is because I chose a thin wire (perhaps the thinnest that is strong enough to use) on purpose. A 2 x 3m loop of 16/0.2 wire, for instance, has a resistance of 0.36Ω, much less than the inductive reactance at 5kHz, and such a loop would not meet the frequency response requirement, the current level being 3dB down, relative to its value at low frequencies, at only 2.9kHz.

Maximum Wire Size for Voltage-Driven Loops

Consider the equations for resistance, inductance and bandwidth together.

$$R = 2\pi f_o L$$
$$R = \rho k/A$$
$$L = 8a \times 10^{-6}$$

For a square loop, k = 4a, so we can substitute:

$$4\rho a/A = 16\pi a f_o \times 10^{-6}$$

Putting in the numerical value of ρ (18 x 10^{-9}) and simplifying:

$$A = 1.432 \times 10^{-3}/f_o$$

Surprisingly, this result is independent of the size of the loop (a cancels in the equation), and it is also valid for rectangular loops. If f_o = 5kHz, A = 0.29 x $10^{-6}m^2$, or $0.29mm^2$. This is the area of the standard 1/0.6mm equipment wire, but single-strand wire is *not* ideal for loops, on mechanical grounds. The area of 7/0.2mm stranded wire is $0.22mm^2$, which gives a bandwidth of 6.6kHz (if there are no other high-frequency losses in the system, of course), and is perhaps the best choice. This wire has been found to carry 8A maximum in loop applications, and is the thickest wire that can be used for single-turn voltage-driven loops of any size, without needing equalisation (treble boost) in the system. The need for a thinner wire occurs when a small loop is required, and the 7/0.2 wire would give too low a load resistance for the amplifier. For example, our 2 x 3m loop would have a resistance of only 0.83Ω (the same as the inductive reactance at 6.6kHz), which is lower than the minimum permissible load resistance for most amplifiers. This explains the remainder of the concern for passing large currents through thin wires.

Largest Voltage-Driven Loop

Since we now know that the thickest wire we can use will carry 8A, we can go on to find the size of loop that needs 8A, and this is the largest single-turn loop that can be voltage-driven without equalisation. Rearranging the field-strength equation for a square loop again:

$$a = 2\sqrt{2}I/\pi H_o s$$

Where 's' is the correction factor for the 1.2m (usually) distance between the listening plane and the loop plane. Unfortunately, 's' depends in a complicated way on 'a', so it is not easy to solve this equation. However, if 'a' turns out to be large compared with 1.2m, so that 's' is nearly 1, we can get a good approximation by assuming 's = 1'. If we take our reduced average value for H_o, i.e. $63mAm^{-1}$, and 8A as the average current rather than the maximum, we get 'a = 114m'. Mind you, it requires no mean amplifier to drive such a big loop! The maximum current is 8 x 5.6 = 44.8A, and the resistance of 456m of 7/0.2mm wire is 37.3Ω. This requires an output voltage capability of 1671V (!), and the maximum power dissipated in the loop is nearly 75kW. The amplifier power rating would have to exceed this. The average power is 'only' I^2R = 64 x 37.3 = 2.4kW, the rest being needed as 'overhead' because of the low peak-to-mean ratio of speech signals.

It probably wouldn't be a good idea to use such a large loop, not least because the overspill would be quite strong for over 100m outside the loop in every direction. Also, the amplifier would be very expensive and bulky, and the electromagnetic forces on the loop wire could even be strong enough to break it in certain circumstances. Such a large area (which may be required to be covered, e.g. a cathedral or exhibition hall) would normally use several loops and amplifiers.

More Turns

It has been suggested that the way to cover large areas without using huge amplifiers is to use loops with many turns. This isn't such a good idea as it seems. The trouble is that, while the resistance of a loop of 'N' turns has 'N' times the resistance of a single turn, it has (nearly) 'N^2' times the inductance. The result is that pure voltage drive requires an impracticably thin wire to achieve the 5kHz bandwidth. Even with equalisation, the voltage required to drive the necessary current through large loops at high frequencies is very large indeed, and even our big single turn required nearly 1.7kV! For loops of a more modest size, the provision of equalisation can permit the resistance to be made negligible compared with the inductive reactance at 5kHz. Such a loop dissipates very little actual power, but the amplifier must still be capable of driving the required current through the inductive reactance. Compared with a voltage-driveable loop, the voltage required is reduced by a factor of $\sqrt{2}$, which can be helpful. It means a reduction by half of the required 'power rating' of the amplifier: more on this later.

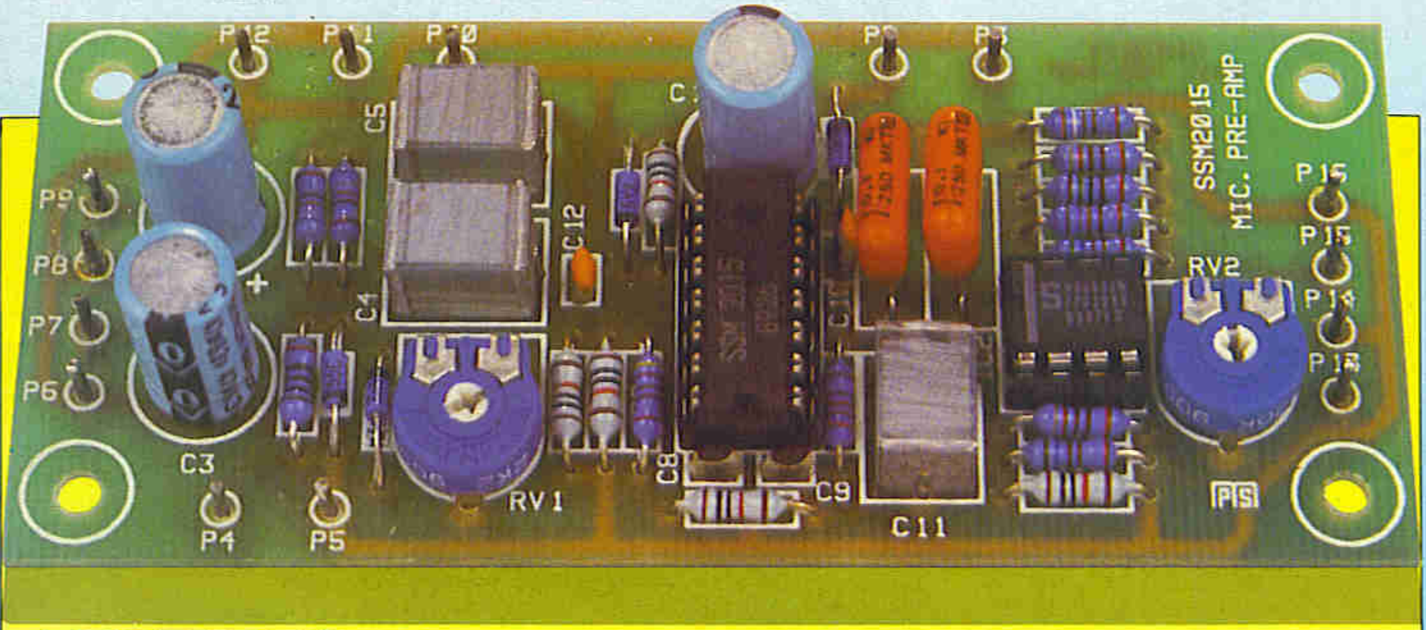
Things to Come

Next time we shall look at the practical details of the household loop amplifier and system, and perhaps the use of equalisers and current-drive amplifiers.

DATA FILE

SSM2015

MICROPHONE PREAMPLIFIER



FEATURES

- **Low Noise**
- **Low Distortion**
- **Differential Inputs**
- **High Slew Rate**
- **Kit Available**

APPLICATIONS

- **Balanced Microphone Preamplifier**
- **Balanced Line Drivers**

Introduction

The SSM2015 is a low noise preamplifier IC featuring low distortion and a wide bandwidth. Voltage gains between approximately 10 and 2000 can be set using different resistor values and the device is ideal for microphone preamplification. True differential inputs make the IC particularly useful for interfacing balanced transducers to equipment with single ended inputs. Figure 1 shows the IC pinout diagram and Table 1 shows typical electrical characteristics for the SSM2015.

IC Circuit Description

The SSM2015 is a true differential amplifier with the feedback return path directly to the emitters of the input stage transistors. Using this system, it is possible to obtain a very good noise figure and high common mode rejection. The input stage current is maintained by an internal feedback loop which is in turn controlled by an external bias resistor allowing programmability and also enabling the noise figure to be optimised for a wide range of

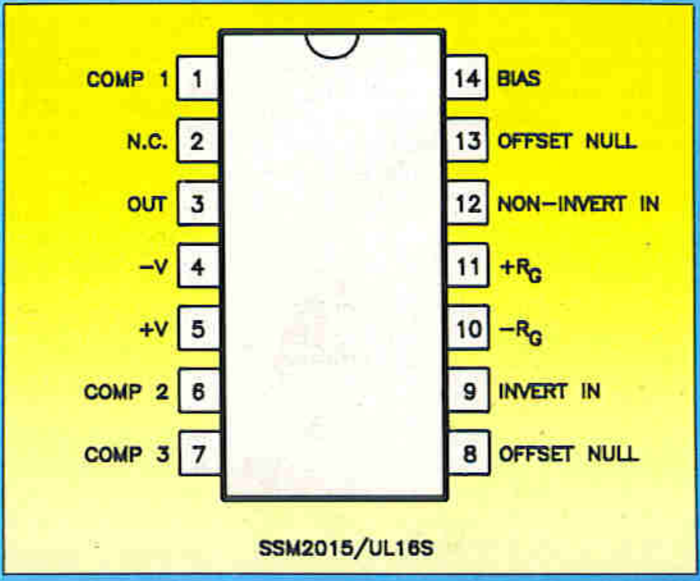


Figure 1. IC pinout.

Parameter	Conditions	Min	Typ	Max
Power Supply Voltage (DC)		±12V	±15V	±17V
Supply Current	±15V		12mA	16mA
Total Harmonic Distortion (THD)	Output Voltage = 7V RMS, Gain = 1000, Frequency = 1kHz		0.007%	0.01%
	Output Voltage = 7V RMS, Gain = 100, Frequency = 1kHz		0.007%	0.01%
	Output Voltage = 7V RMS, Gain = 10, Frequency = 1kHz		0.01%	0.015%
Output Current	Source	15mA	25mA	
	Sink	8mA	14mA	
Bandwidth (−3dB)	Gain = 10		1MHz	
	Gain = 100		700kHz	
	Gain = 1000		150kHz	
Output Voltage Swing	2k load	±10.5V	±12.5V	
Slew Rate			6V/us	
Common Mode Input Impedance			50M	
Differential Mode Input Impedance	Gain = 10		20M	
	Gain = 100		5M	
	Gain = 1000		0.5M	
Common Mode Voltage Range		±4V	±5V	

Above specification for ±15V power supply, Temperature = 25 deg C.

Table 1. SSM2015 typical electrical characteristics.

source impedances.

Figure 2 shows a typical application circuit for the SSM2015. Overall frequency compensation for the circuit is provided by capacitors C1 and C2 while C3 compensates the input stage current regulator. The values of C1 and C2 are dependant on the value of bias resistor, R_{bias} and typical values range from 15pF to 30pF for C1 and 5pF to 15pF for C2.

The bandwidth of the SSM2015 is dependant on gain and the value of the bias resistor (R_{bias}). Under worst case conditions (gain = 1000, R_{bias} = 150k) the bandwidth is in excess of 70kHz; however, at lower gains and higher bias currents, −3dB bandwidths up to 1MHz are possible.

The SSM2015 inputs are completely floating and to prevent the input voltage from exceeding the common mode range, it is necessary to provide a DC connection to a suitable point in the circuit (usually 0V). A common method of achieving this is to connect one side of the input transducer to 0V. Another method is to let the transducer float and connect each input to the 0V line using resistors; the value of these should be kept as low as possible for noise immunity purposes and in practice may be any value up to a maximum of around 10k. For optimum noise performance balanced transducers should be used and these may be connected directly to the IC inputs without additional bias resistors.

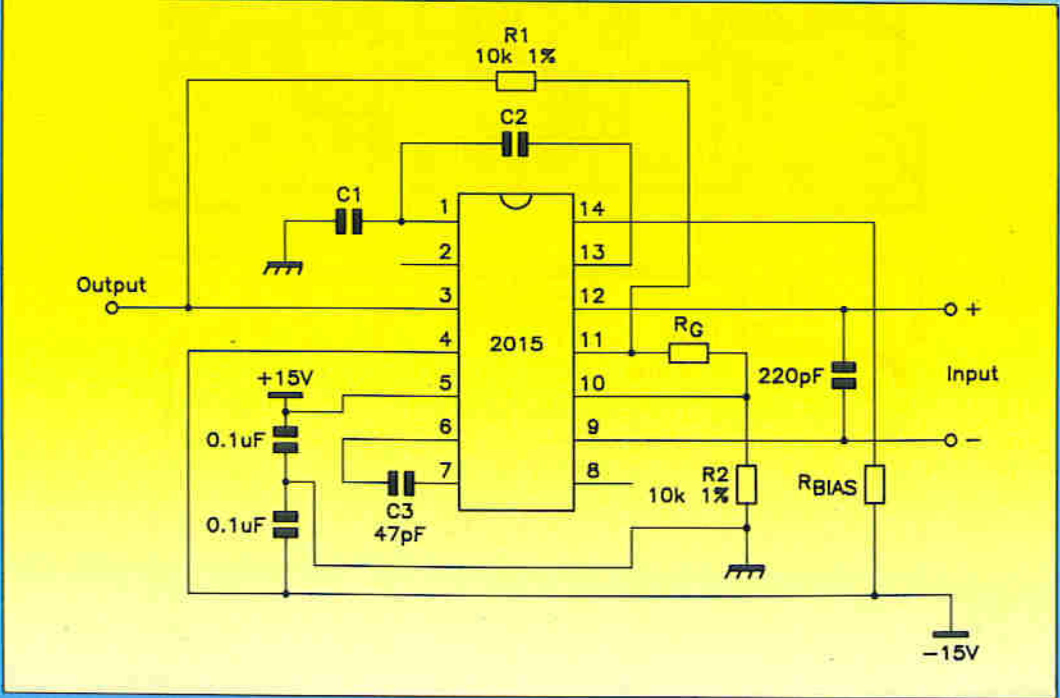


Figure 2. Typical application circuit.

Kit Available

A kit of parts using a high quality, fibre-glass PCB is available for a basic application circuit using the SSM2015. Figure 3 shows the circuit diagram of the module and Figure 4 shows the legend of the PCB. The circuit will handle either balanced or single ended inputs and additional components are used to give a balanced output as well as the standard single ended output.

A split rail power supply of between ±12V and ±17V is required to power the module. The supply should be capable of delivering at least 50mA and should be properly smoothed

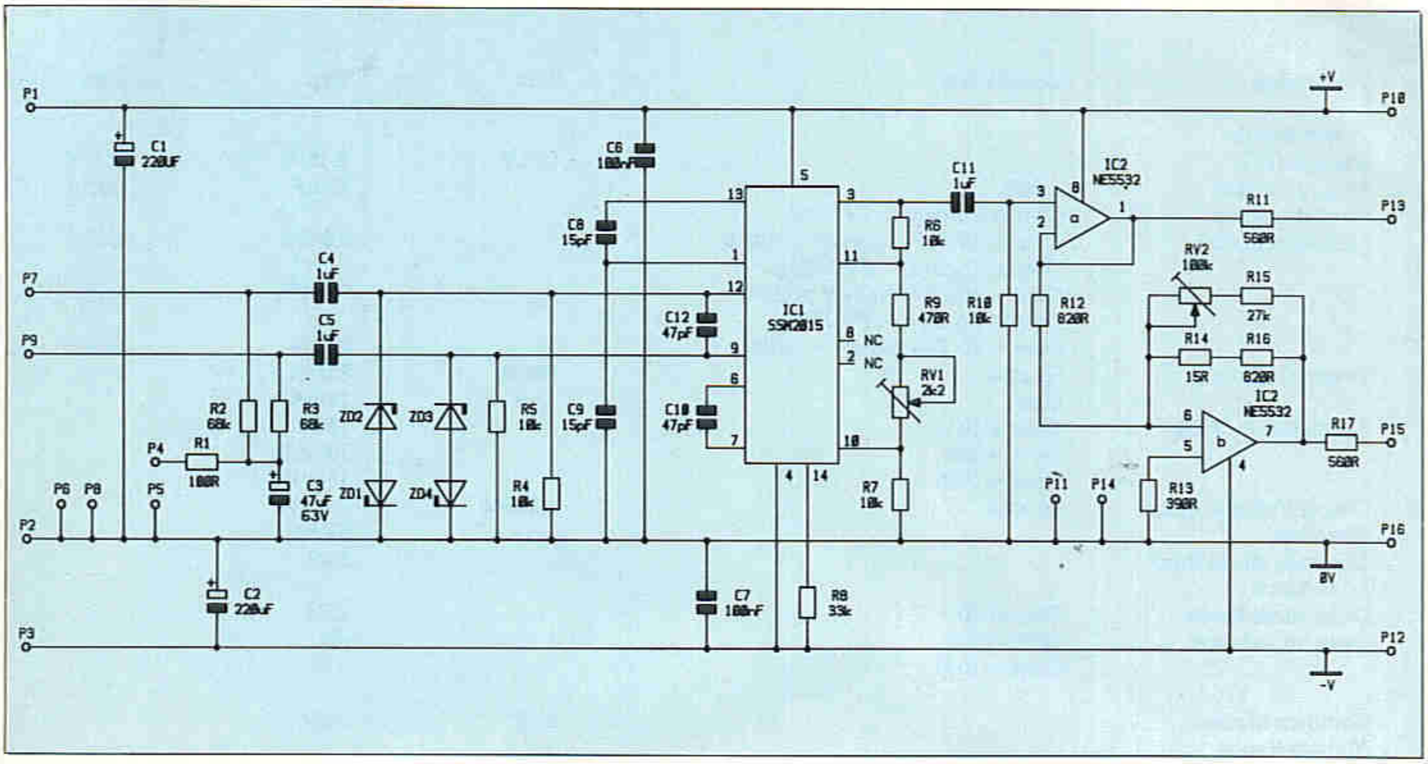


Figure 3. Circuit diagram.

and regulated. Connection information for the module is shown in Figure 5.

Presets RV1 and RV2 provide adjustable gain. The overall gain of the preamplifier is adjusted by RV1 and may be set between approximately 10 and 50. Maximum gain is achieved when RV1 is set to the fully anti-clockwise position. RV2 allows fine adjustment of the gain of IC2b either side of 0 so that this can be matched to the gain of IC2a for correct balancing. If no test equipment is available, RV2 should be set to the centre of its travel; although this does not necessarily provide optimum matching of the two output levels, a reasonable degree of balance should be obtained. Balanced inputs are connected to P7 (+i/p), P8(0V) and P9(−i/p). If a single ended output is required this may either be taken between P13(o/p) and P14(0V) or between P15(o/p) and P16(0V). For balanced operation, output connections are made to P13(o/p), P14(0V) and P15(o/p). Note that the output at P13 is 180 degrees out of phase with the output at P15.

Additional facility is provided to allow a low current power supply up to a maximum of 60V to be coupled onto the input lead for phantom powering microphones and similar equipment. Zener diodes, ZD1 - ZD4 provide input protection for the SSM2015 from any voltage transients that may occur when connecting microphones/microphone power supplies to the module. If the phantom power facility is not required, then the components used in this part of the circuit (R1, R2, R3 and C3) need not be fitted.

Applications

The preamplifier module may be used in a wide range of applications but is particularly useful when interfacing balanced

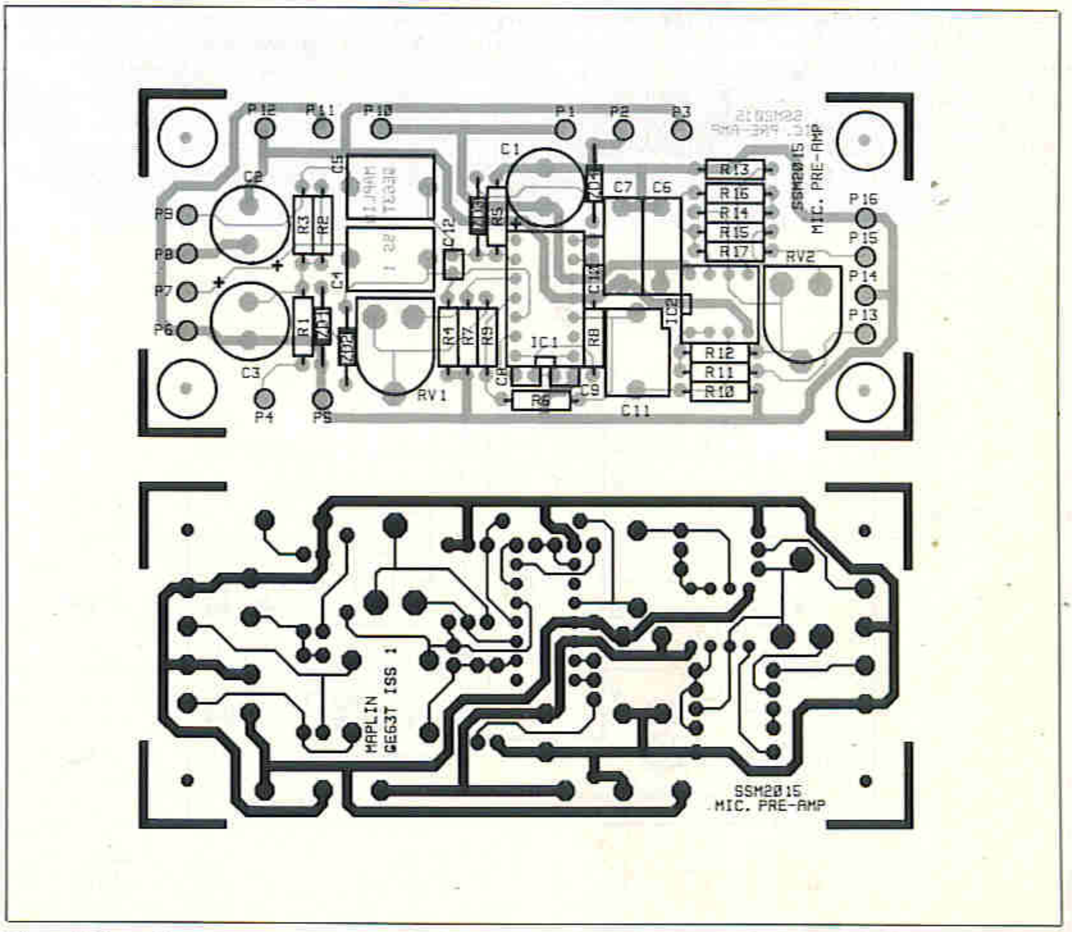


Figure 4. Legend.

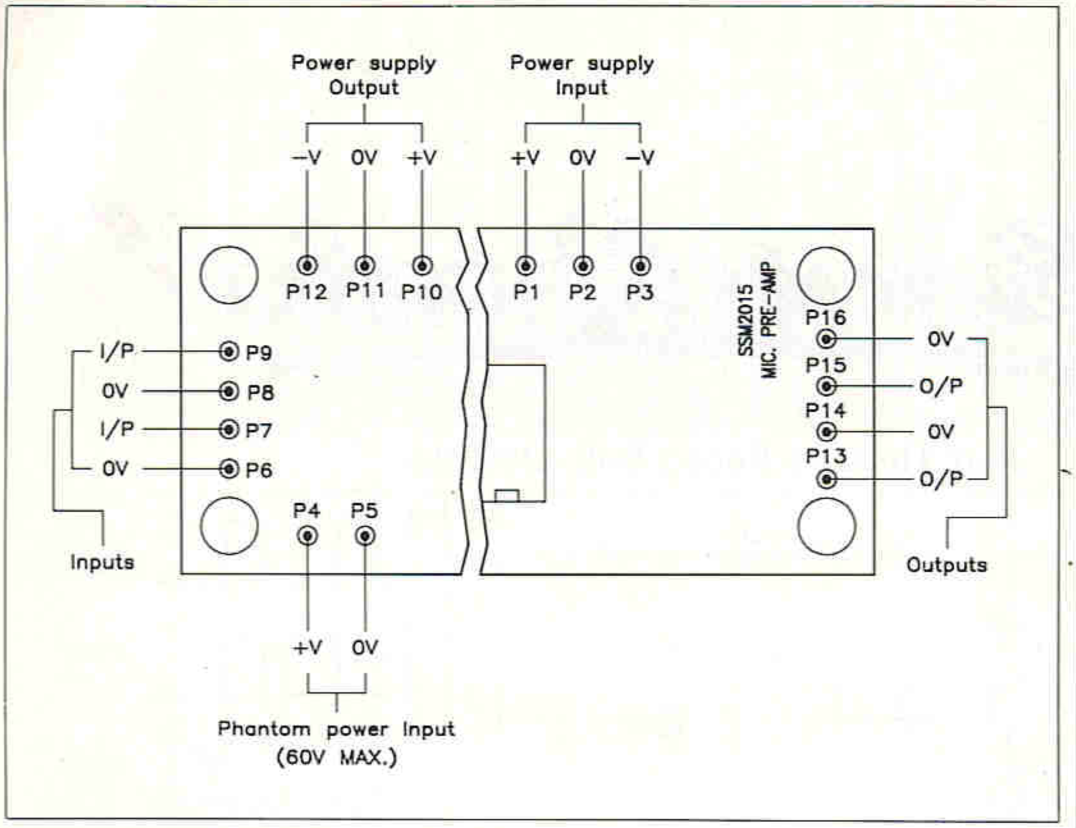


Figure 5. Wiring diagram.

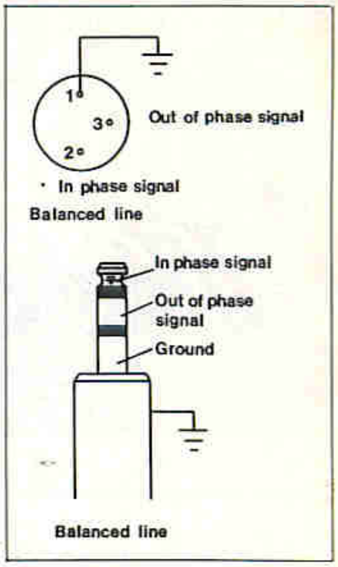


Figure 6. Standard XLR and jack connections for balanced line.

transducers (microphones) to single ended equipment. Balanced connections are normally made using XLR connectors and the standard wiring format for this type of connector is shown in Figure 6. Stereo jack connectors may also be used and typical connections for these are also shown. Finally, three additional pins P10(+V), P11(0V) and P12(−V) are included for low current (500mA maximum) power supply connections to auxiliary equipment; the pins are connected electrically via tracks on the PCB to P1, P2 and P3.

Table 2 shows the specification of the prototype preamplifier.

Supply Voltage	±12V to ±17V DC
Supply Current (Quiescent)	20mA at ±15V
Total Harmonic Distortion (THD) measured at 1kHz	Less than 0.02%
Gain: RV1 set to minimum gain	21.0dB
RV1 set to maximum gain	33.5dB
Maximum input voltage (for 9V RMS output, gain set to maximum, ±15V power supply)	190mV RMS
Maximum input voltage (for 9V RMS output, gain set to minimum, ±15V power supply)	800mV RMS
PCB dimensions	43mm x 99mm

Table 2. Specification of prototype module.

SSM2015 MICROPHONE PREAMPLIFIER PARTS LIST

Resistors: All 0.6W 1% Metal Film			
R1	100R	1	(M100R)
R2,3	68k	2	(M68K)
R4,5,6,7,10	10k	5	(M10K)
R8	33k	1	(M33K)
R9	470R	1	(M470R)
R11,17	560R	2	(M560R)
R12,16	820R	2	(M820R)
R13	390R	1	(M390R)
R14	15R	1	(M15R)
R15	27k	1	(M27K)
RV1	Hor Encl Preset 2k2	1	(UH01B)
RV2	Hor Encl Preset 100k	1	(UH06G)
Capacitors			
C1,2	220µF 35V PC Electrolytic	2	(JL22Y)
C3	47µF 63V PC Electrolytic	1	(FF09K)
C4,5,11	1µF Poly Layer	3	(WW53H)
C6,7	100nF Polyester	2	(BX76H)
C8,9	15pF Ceramic	2	(WX46A)
C10,12	47pF Ceramic	2	(WX52G)
Semiconductors			
IC1	SSM2015	1	(UL16S)
IC2	NE5532	1	(UH35Q)
ZD1−4	BZX61C6V2	4	(QF48C)
Miscellaneous			
P1-16	Pin 2145	1pkt	(FL24B)
	DIL Socket 8-Pin	1	(BL17T)
	DIL Socket 14-Pin	1	(BL18U)
	PC Board	1	(GE63T)
	Constructors Guide	1	(XH79L)

All the above items are available in a kit:
Order As LP42V (SSM2015 Mic Preamp Kit) Price £10.95

The following item is also available separately:
SSM2015 PCB **Order As GE63T Price £2.25**

SWITCHED MODE POWER CONVERSION

The Secrets Revealed!

Part Three by Robert Ball A.M.I.P.R.E.

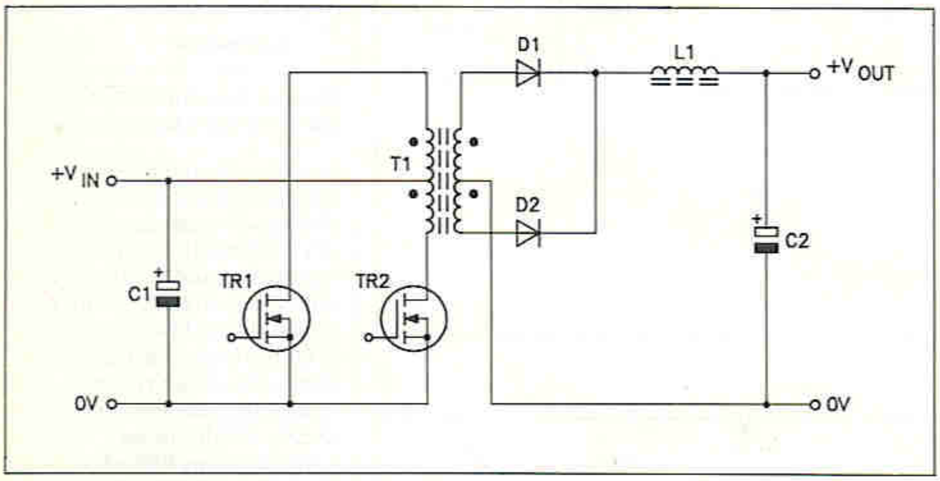


Figure 12. A Push-Pull Converter.

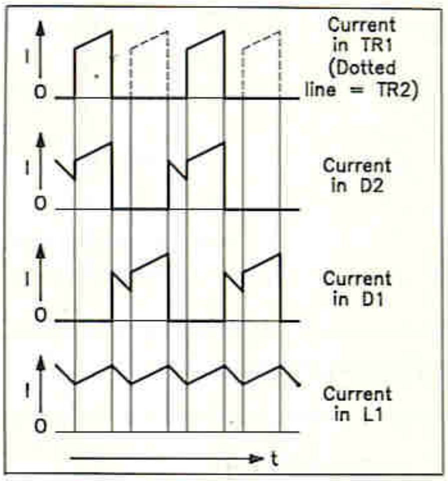


Figure 13. Current Waveforms in a Push-Pull Converter.

Resumé

In part two we dealt with the flyback regulator and the boost regulator, and we also looked at the operation of the forward converter and the flyback converter. In part three we will, in conclusion, examine the operation of the push pull converter, and briefly, the half bridge and the full bridge converters. We will then take a look at a complete switched mode power supply and its control circuitry.

Push Pull Converter

Figure 12 shows the circuit for a push-pull converter. The main differences between this and anything we have looked at previously are the addition of a second switching transistor, and a transformer with both a centre tapped primary and secondary. This circuit belongs to the feed forward converter family, as energy is transferred to the output capacitor during the conduction period of the switching transistors. When TR1 switches on, current flows through the 'upper' half of T1's primary and the magnetic field in T1 expands. The expanding magnetic field in T1 induces a voltage across T1 secondary, the polarity is such that D2 is forward biased and D1 reverse biased. D2 conducts and charges the output capacitor C2 via L1. L1 and C2 form an LC filter network. When TR1 turns off, the magnetic field in T1 collapses, and after a period of dead time (dependent on the duty cycle of the PWM drive signal), TR2 conducts, current flows through the 'lower' half of T1's primary and the magnetic field in T1 expands. Now the direction of the magnetic flux is *opposite* to that produced when TR1 conducted. The expanding magnetic field induces a voltage across T1 secondary, the polarity is such that D1 is forward biased and D2 reverse biased. D1 conducts and charges the output capacitor C2 via L1. After a period of dead time, TR1 conducts and the cycle repeats.

There are two important considerations with the push pull converter: 1. Both transistors must not conduct simultaneously, as this would effectively short circuit the supply. Which means that the conduction time of each transistor must not exceed half of the total period for one complete cycle, otherwise conduction will overlap. 2. The magnetic behaviour of the circuit must be uniform, otherwise the transformer may saturate, and this would cause destruction of TR1 and TR2. This requires that the individual conduction times of TR1 and TR2 be exactly equal and the two halves of the centre-tapped transformer primary be magnetically identical. These criteria must be satisfied by the control and drive circuit and the transformer.

The output voltage Vout equals the average of the waveform applied to the LC filter.

$\mathrm{Vout} = \mathrm{Vin} \times (n2 / n1) \times \alpha$

where:

$n2$ = secondary turns on T1 between one end and the centre tap (i.e. ½ the total number of turns)

$n1$ = primary turns on T1 between one end and centre tap (i.e. ½ the total number of turns)

$\alpha = (\mathrm{Ton}_{TR1} + \mathrm{Ton}_{TR2}) / \tau$

$\tau = 1 / f$

Note:

$\mathrm{Ton}_{TR1} = \mathrm{Ton}_{TR2} \leqslant 0{\cdot}5 \times \tau$

τ = Total period for one complete cycle where both TR1 and TR2 have conducted.

The control circuit monitors Vout and controls the duty cycle of the drive waveform to TR1 and TR2.

If Vin increases, the control circuit will reduce the duty cycle accordingly, so as to maintain a constant output. Likewise if the load is reduced and Vout rises the control circuit will act in the same way. Conversely, a decrease in Vin or increase in load, will cause the duty cycle to be increased. Figure 13 shows associated waveforms from the push pull converter.

Half Bridge and Full Bridge

Figure 14a shows the circuit for the half bridge converter and Figure 14b the circuit for the full bridge converter. Briefly, these circuits are similar to the push pull circuit, except that a centre tapped primary is not required. The reversal of the magnetic field is achieved by reversing the direction of current flow through the primary winding. Half and full bridge converters will be found in very high power applications.

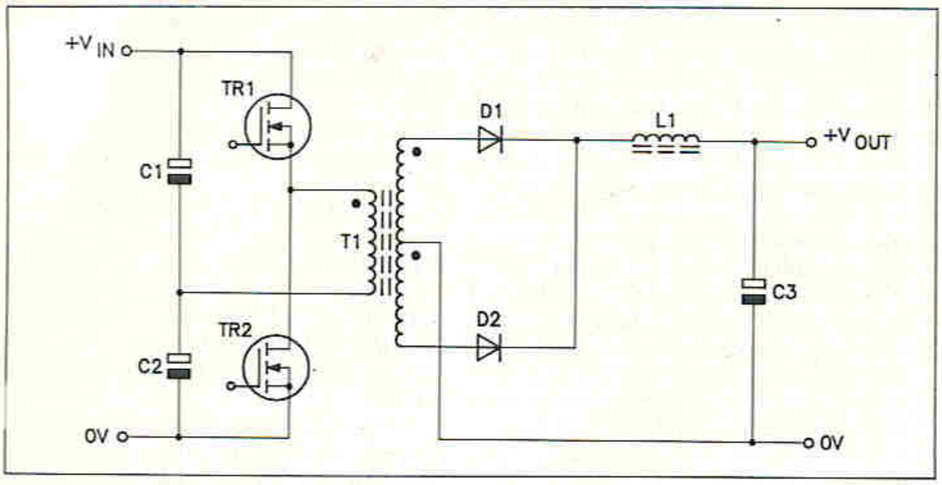


Figure 14a. A Half Bridge Converter.

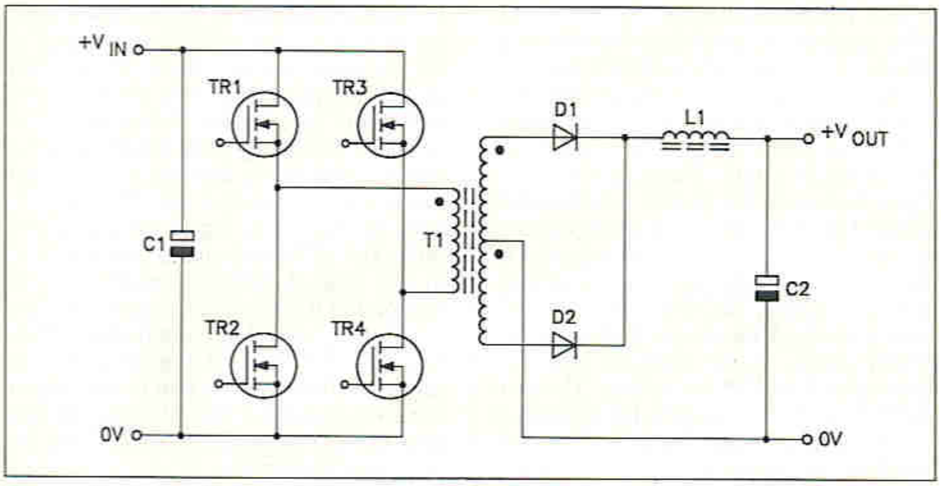


Figure 14b. A Full Bridge Converter.

For the half bridge circuit, the output voltage Vout equals the average of the waveform applied to the LC filter.

$Vout = (Vin / 2) \times (n2 / n1) \times \alpha$

where:

n2 = secondary turns on T1 between one end and centre tap (i.e. ½ the total number of turns)

n1 = primary turns on T1

$\alpha = (Ton_{TR1} + Ton_{TR2}) / \tau$

$\tau = 1 / f$

Note: $Ton_{TR1} \equiv Ton_{TR2} \leqslant 0{\cdot}5 \times \tau$

The behaviour of the Control Circuit, which monitors Vout, and provides drive to TR1, is identical to that of the push-pull converter.

For the full bridge circuit, the output voltage Vout equals the average of the waveform applied to the LC filter.

$Vout = Vin \times (n2 / n1) \times \alpha$

where:

n2 = secondary turns on T1 between one end and the centre tap (i.e. ½ the total number of turns)

n1 = primary turns on T1

$\alpha = (Ton_{TR1} + Ton_{TR2}) / \tau$

$\tau = 1 / f$

Note:

$Ton_{TR1} \equiv Ton_{TR2} \leqslant 0{\cdot}5 \times \tau$

τ = Total period for one complete cycle where both TR1 and TR2 have conducted.

Diagonal pairs of transistors will alternately conduct, thus achieving current reversal in the transformer primary. This can be illustrated as follows – with TR1 and TR4 conducting, current flow will be 'downwards' through the transformer primary, and with TR2 and TR3 conducting, current flow will be 'upwards' through the transformer primary.

The control circuit monitors Vout and controls the duty cycle of the drive waveform to TR1, TR2, TR3 and TR4.

The Control Circuit operates in the same way as for the half bridge and push pull converters, except that four transistors are being driven instead of two.

Mains Operated Switched Mode Forward Converter

Having dealt with the main circuit configurations of switched mode regulators and switched mode converters, a complete power supply can be considered, albeit in slightly simplified form.

Figure 15a shows a circuit diagram for the power stages of a step down switched mode power supply and Figure 15b shows a simplified control circuit. Figure 15c illustrates operation in block diagram form. This power supply is of the forward converter type and is often referred to as an 'off-line' SMPS as input power is derived 'off the mains line'. Dealing with the power stages first: The input to the power supply is 240V AC mains, this is fed via FL1, an electro-magnetic and radio-frequency interference filter, to on/off switch S1. The AC mains is then fed via fuse FS1 to the bridge rectifier BR1 and reservoir capacitor C1. The DC potential across C1 will be in the order of 340V. Resistor R1 may at first seem to be a curious addition to the circuit, but its role is vital. R1 is a low value resistor (approximately 2 to 4 ohms) and its purpose is to limit the supply surge current at switch-on caused by C1 charging; thus reducing the stress on BR1 and C1 itself. TR1, a high voltage MOSFET power

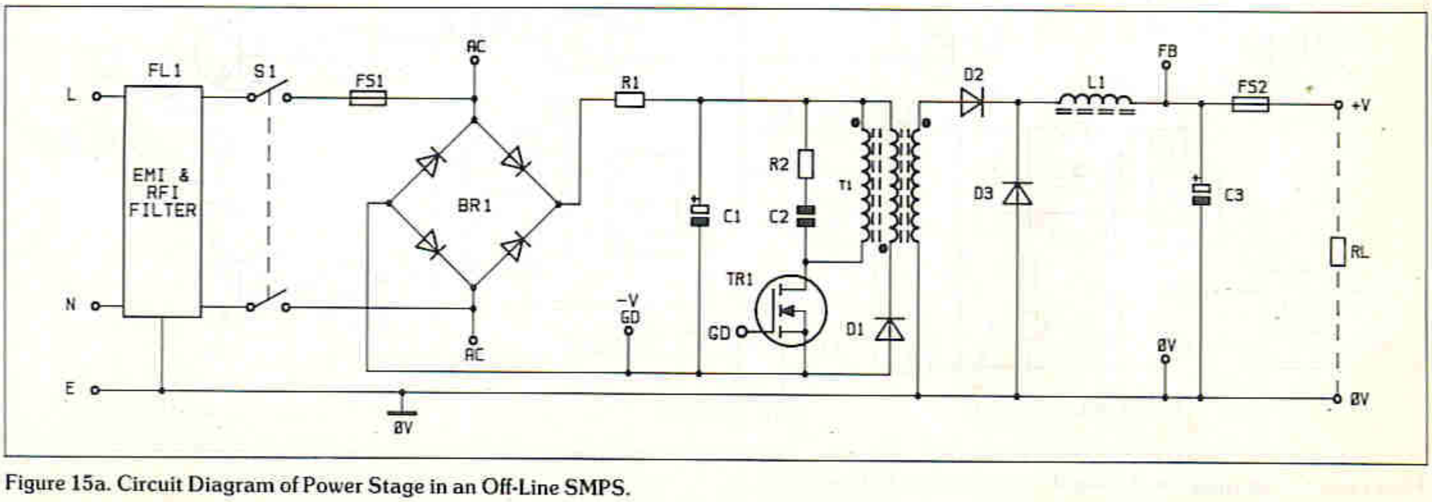


Figure 15a. Circuit Diagram of Power Stage in an Off-Line SMPS.

transistor, is used as a high speed switch to drive pulses of current through transformer T1. The frequency of operation for TR1 will normally be in the range of 25 to 250kHz, depending on the application. R2 and C2 form a snubber network to reduce spikes and switching noise. T1 is a ferrite cored, high frequency transformer. D2 is the rectifier diode and D3 is the flywheel diode. L1 serves as an energy storage inductor and forms part of the LC filter combination L1/C3. C3 is the output capacitor. Regulation is achieved by monitoring the output voltage at the point marked 'FB' and adjusting the pulse width of the drive waveform to TR1. Fuse FS2 serves as overload and short circuit protection. Very often FS2 will be replaced with an electronic protection circuit that will shut down the power supply in the event of an overload or short circuit.

Control Circuitry

Driving the power stages and taking care of regulation is the control circuit shown in Figure 15b, which shows a simplified circuit to illustrate the fundamentals of operation. The control circuit itself requires power to operate, and this is provided by the block designated 'Aux. Supply'. The auxiliary supply may take several forms, and in this instance it derives its power from the 240V AC mains supply input to provide the low voltage auxiliary supply. The circuitry required to perform the control functions will normally be in the form of an integrated circuit. In Figure 15b the blocks labelled with a letter ('a' to 'm') are contained in an integrated circuit, whilst the other discrete components are external to the device. Block 'a' is a highly stable oscillator which produces a sawtooth waveform, timing components R1 and C1 set the operating frequency. A stable reference voltage (VREF) is provided by block 'b', this is used by the error amplifier and other circuitry. Control of the output pulse width is under control of the Dead Time Control Comparator, 'c', and the Pulse Width Modulator (PWM) Comparator, 'e'. These two comparators each compare a control voltage with the sawtooth oscillator waveform. The output of the two comparators is ORed together, 'f', before being fed to the output control circuitry. The Dead Time Control Comparator is used to provide a 'soft start'; this brings the output of the power supply up to its working level over a short period of time (50ms) after switch on. This reduces stress on the components in the power stages at switch-on. The time constant for the 'soft start' is provided by R2 and C2. The Error Amplifier, 'd', is responsible for comparing the output voltage of the power supply with a reference. If the output voltage tries to deviate from its correct value, because of changes in either load and/or line voltage, the error amplifier output changes to maintain the correct output voltage. The voltage at the output of the power supply is monitored at the point marked 'FB' on Figure 15a, this voltage is coupled to the error amplifier circuitry via an Opto Isolator (Figure 15b). The Opto Isolator is required to maintain isolation between the low voltage output and the live power stages. The opto isolation circuitry has been shown as a block for clarity. The output from the Opto Isolator is fed to the non-inverting input of the Error Amplifier via a potential divider, R6 and R9, where it is compared to the reference voltage provided by another potential divider, R3, R4 and RV1. RV1 serves to adjust the output voltage of the power supply to the required level. C3 decouples the reference voltage. The gain of the error amplifier is set by the network of components, R5, R8, C4 and R7. The error amplifier is essentially a non-inverting operational amplifier circuit with the low frequency gain being set by R5 and R8.

Error Amplifier LF Gain = 1 + (R8 / R5)

The combination of inductive and capacitive components in the power stages will cause phase shift, and at certain frequencies it is a possibility that the feedback loop could become unstable and break into oscillation, which is, to say the least, highly undesirable! The answer to this is to provide frequency/phase compensation; this is provided by C4 and R7. As the frequency rises, the gain of the amplifier is reduced, thus ensuring stability. The gain of the error amplifier at a given frequency is thus:

(where f is the frequency)

Impedance of frequency compensation network:

$X_c = 1 / (2 \times \pi \times f \times C4)$

$Z = \sqrt{(R7^2 + X_c^2)}$

Total Feedback Impedance:

$Z_f = (Z \times R8) / (Z + R8)$

Error amplifier Gain at Frequency $f = 1 + (Z_f / R5)$

The integrated circuit used in this example has two outputs, and can be 'programmed' to use these for either push-pull or single ended applications. Selection of the required mode is achieved by taking the inputs of the two AND gates (h) and (i) to either VREF for push-pull or 0V for single ended. When in push-pull mode, the frequency of the drive signal is half that of the oscillator, this is due to the action of bistable (g). The bistable ensures that the two output transistors (l) and (m) never conduct together and that the duty cycle of each drive signal never exceeds 50%. The 50% maximum is a requirement in this type of forward converter power supply. For this reason the push-pull mode is selected, even though only one output transistor (l) is used. NOR gates (j) and (k) steer the PWM drive signal to the output transistor under the control of the bistable outputs. R11 provides an emitter load for the output transistor.

Winding It Up

In part three we have looked at the push pull converter, and the half bridge and full bridge converters. We also examined a complete power supply and its control circuitry; thus concluding this short series on the principles of switched mode power conversion. The series has only briefly scratched the surface of this fascinating area of electronics, leaving practical design and new developments completely untouched.

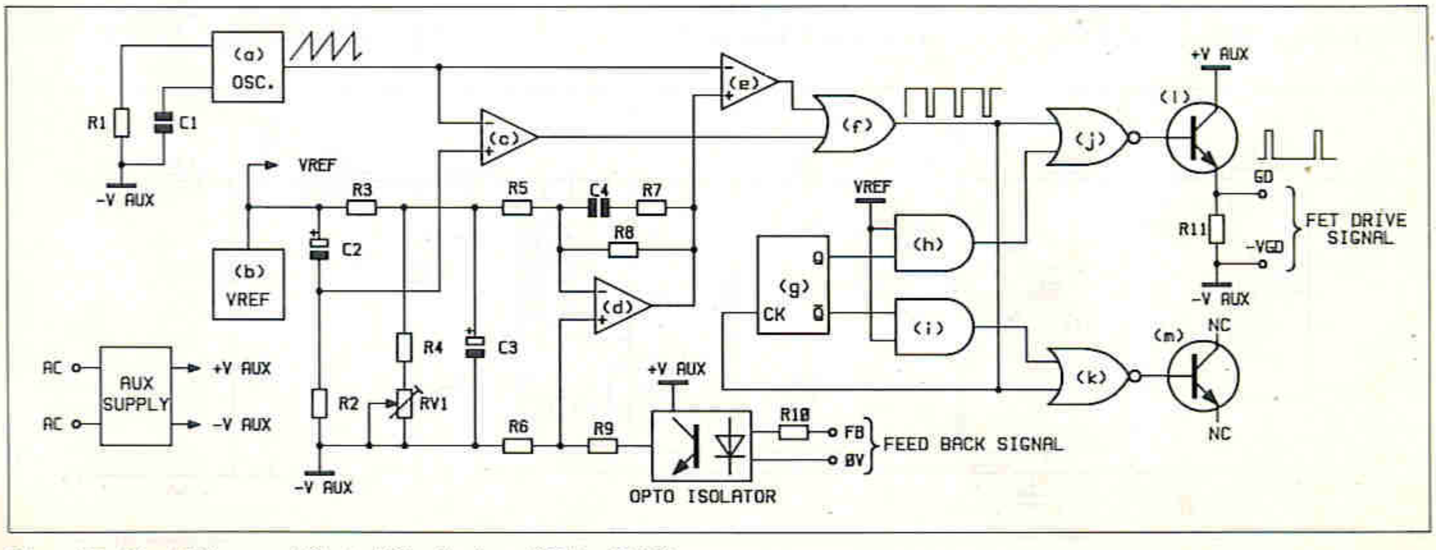


Figure 15b. Circuit Diagram of Control Circuitry in an Off-Line SMPS.

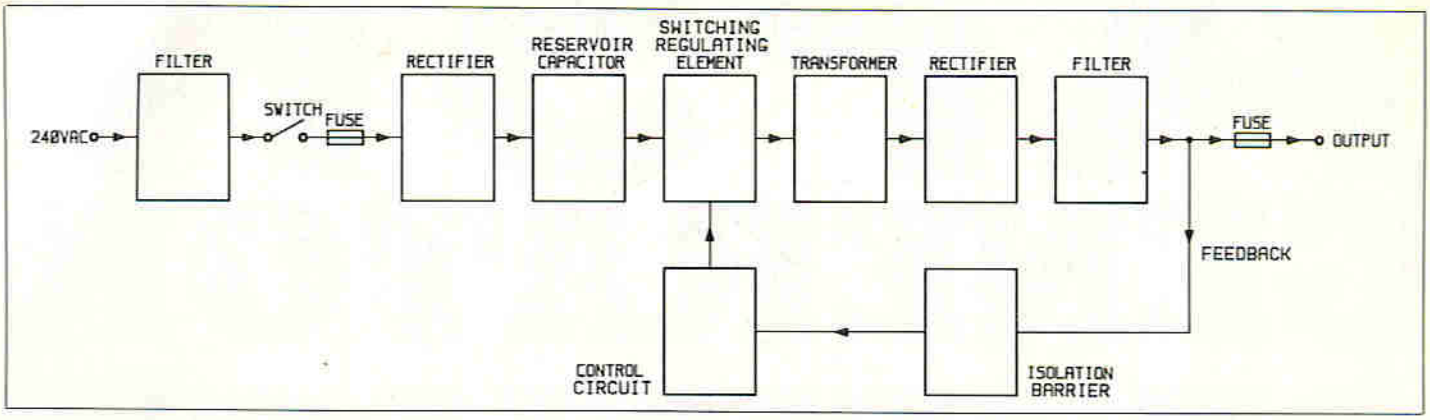


Figure 15c. Block Diagram of an Off-Line SMPS.

Indeed a complete series could be devoted to one regulator or converter topology alone! In the near future it is intended to present some practical designs for switched mode power supplies; watch this space!

Feedback

If you have any comments, suggestions or project ideas regarding particular applications for switch mode power supplies then please write to 'SMPS, Electronics - The Maplin Magazine, P.O. Box 3, Rayleigh, Essex, SS6 8LR.'

References

SGS Power Supply Application manual. Motorola Power MOSFET Transistor Databook. Unitrode Semiconductor Databook. Unitrode Applications Handbook. Transformer Core Selection for SMPS, Mullard. Soft Ferrites – Properties and Applications, E.C. Snelling. Switchmode – A Designer's Guide, Motorola. SMPS – Technology and Components, Siemens. Texas Instruments Linear Circuits Databook. Analogue Electronics Handbook, T.H. Collins.

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.
Please print all advertisements in bold capital letters. Box numbers are available at £1.50 each. Please send replies to Box Numbers to the address below. Please send your advertisement with any payment necessary to: Classifieds, Maplin Mag., P.O. Box 3, Rayleigh, Essex SS6 8LR.

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

VARIOUS

GOULD DIGITAL STORAGE SCOPE £450, Colour Bar Generator £30, Philips Timer/Counter 120MHz £150, Function Generator £70. All as new. Tel: 0784 259448 eves.

DENCO G.P. COILS Ranges 2-3-4-5, blue-yellow-red. 12 coils £18, carriage extra. Seon Smyth, 'De Porres', 67 East Princes Street, Helensburgh G84 7DG. Tel: 0436 71181.

3 SLIGHTLY USED Etri 240V 120mm fans at £4.50 each or £12 the lot. Tel: 0543 491867.

FOR SALE (ex-equipment) 24V Mechanical Counters £5. Tagged NiCads AA £0.85, C £1.60. Attractive seven segment displays 1 inch high, 4 digit £5, 5 digit £6. Add £2 P & P. Send cheques to J. Edwards, Aitkenmoor, Annanwater, Moffat DG10 9LS.

PHILIPS VR2022 VIDEO 2000 RECORDER little used, in perfect condition with makers Service Manual Instruction Book and spare cassettes £120. 2 VCR 97 6 inch Cathode Ray Tubes, 1 VCR 517 6 inch Cathode Ray Tube, with bases and M/R screens. Best offer secures, will separate. Various valves, old and modern. Details on request. Tel: Banbury 258708.

MAPLIN NICAM DECODER BOARD fully working, will sell for £80 for quick sale. G.J. Eida, 14 Hurstwood Avenue, Bexley, Kent DA5 3PH. Tel: 0322 522315.

MAPLIN DIGITAL MULTI-TRAIN CONTROLLER unused, Maplin Workshop tested. Plus 2 train receiver kits, one made and tested. £35. Tel: 0225 429644.

GIANT CLEAROUT! Components, boards, terminals, disk drives – everything must go! Tel: 0785 41957.

FLUKE 85 MULTIMETER 3.75 digit, auto-ranging, analogue/digital – 11 functions, 40 ranges. As new, £65 o.n.o. Maplin M205 Sweep Function Generator 0.2Hz – 2MHz C/W BNC lead and 50OHM 'T' piece. As new, £100 o.n.o. Tel: 0661 36434.

CLEARING 74LS TTL CMOS 4049/50 and EPROM's. 1,000 chips all less than half normal price. Phone (0702) 216478 or send SAE for list to: 21 North Street, Great Wakering, Essex SS3 0EL.

MUSICAL

MAPLIN 'MATINEE' ELECTRONIC ORGAN professionally built, 2 keyboards, pedals, rhythms, drawbar voicing, rotorsound, etc. Circuit data for easy maintenance, roll top cabinet, bench. Offers around £150. Tel: Woking 773620.

GOOD HOME WANTED for Maplin MES53 organ. 2 x 61-note manuals, drawbars, etc. In home-made cabinet. Offers or willing to swap. Buyer collects. Tel: Redditch (0527) 23385.

COMPUTERS

CORONA PPC 21 complete business set-up inc. Epson P80RA printer, and keyboard + loads of disks/manuals (inc. Multimate and Symphony). Bought from abroad hence 115V/60Hz – UK transformer included. Offers. Tel: Mike Hughes, 0626 54397 eves.

ACORN ELECTRON with manuals and connecting leads. Includes £160 of software. Joystick and interface, plus complete set of accompanying 'Input' magazines (worth £50). £100 o.n.o. Tel: 0234 711704.

Z80 CMOS S.I.O. IC's for sale (UJ61R). In original unopened packaging, only £4 each (Maplin's price £7). Tel: Rolf on 0234 766087.

ONE ASCII KEYBOARD parallel output, 58 keys. Never been used, still boxed. £100 o.n.o. Tel: 0703 330019.

SINCLAIR ZX PRINTER requires replacement styli, offers. Tel: Ian on 031 339 2163.

MICROLINK MULTI-SPEED, (V21/22/23), leads, PSU, PCW8512, 2xFDD, 512KRAM, DMNLQ printer, RS232/C, RTC, PD and commercial S/W, also £110 worth of blank discs, 30 8000+ mags, AMX mouse, games, books. Call Liverpool 051 931 4271 or 051 924 5310.

FOR SALE Master Compact, 2nd drive, joystick, digimouse, comal ROM, printer lead. Software includes Artroom, Exile, Elite and more. Sell the lot for £360 o.n.o. Tel: (081) 508 7648 eves.

FOR SALE Interak Z80 Computer system, home built, fully expandable, very solid, OPM+, 2 x 3.5 inch disk drives, 2 Basics, Pascal, Assembler, lots of extras £450. Mel Saunders, 7 Drumcliff Road, Thurnby Lodge, Leicester LE5 2LH.

WANTED

MODEM AND SOFTWARE WANTED for BBC Model B. Must be under £35 but in good condition. Tel: 0754 67890 after 4pm.

I WOULD LIKE to hear from any radio control model builders. I want to build a boat, and especially need to hear from people who have used the Maplin radio control kits, speed control, etc. It would seem possible to control servos and speed controllers, etc., by using pulses produced by FOR/NEXT LOOPS from a computer, anyone done it? Any ideas, etc. Please write to Mel Saunders, 7 Drumcliff Road, Thurnby Lodge, Leicester LE5 2LH.

HEY YOU! Have you got any Cart machines or disco lighting effect units for sale? If so, send details to: Dafydd Rees, 14 Bank Buildings, Llandeilo, Dyfed SA19 6BU.

CIRCUITS WANTED information for Siemens 0-25MHz test set D+G+W2021. Advance PSU type DC358. Philips digital multimeter PM2513A. Levell testmeter type TM11. Contact: Mr Perry, 216 Marlpool Lane, Kidderminster DY11 5DL.

DISCIPLE INTERFACE V3B DOS or Plus D, must be complete with handbook and DOS software tape/3.5 inch disc, and in perfect order. Contact: Mr M Perry, 216 Marlpool Lane, Kidderminster, DY11 5DL.

WANTED, MUSIC 500/5000 (BBC B) with software and manual(s). Also Brother M1009/Centronics GLP tractor feed. Must be cheap owing to limited budget. Tel: (0754) 67890.

WANTED, MO83 TOP-OCTAVE GENERATOR CHIP (discontinued item). K. Vickers, 58 Elmside, Exeter, Devon EX4 6LR.

BACK ISSUES OF ELEKTOR ELECTRONICS WANTED No.s 105 to 137. Send price and surface mail cost to: Mr Anda Chang, Jl. Wayang 20, Bandung 40262, Jawa-Barat, Indonesia.

EPROM PROGRAMMER WANTED must be capable of programming 2716 EPROM's. Tel: Tim on 0536 373626; or write to Bocase Farm, Brigstock, Kettering NN14 3HZ.

BEGINNER TO ELECTRONICS REQUIRES components for nothing or a small price. Will pay for postage and packing. Mr Dean, Blenheim, Walton Lane, Bosham, Nr Chichester, W.Sussex PO18 8QF.

AFSK GENERATOR

- ★ *Easy Construction*
- ★ *Crystal Controlled Oscillator*
- ★ *On-board Voltage Regulator*
- ★ *No Alignment Required*
- ★ *Simple Testing*

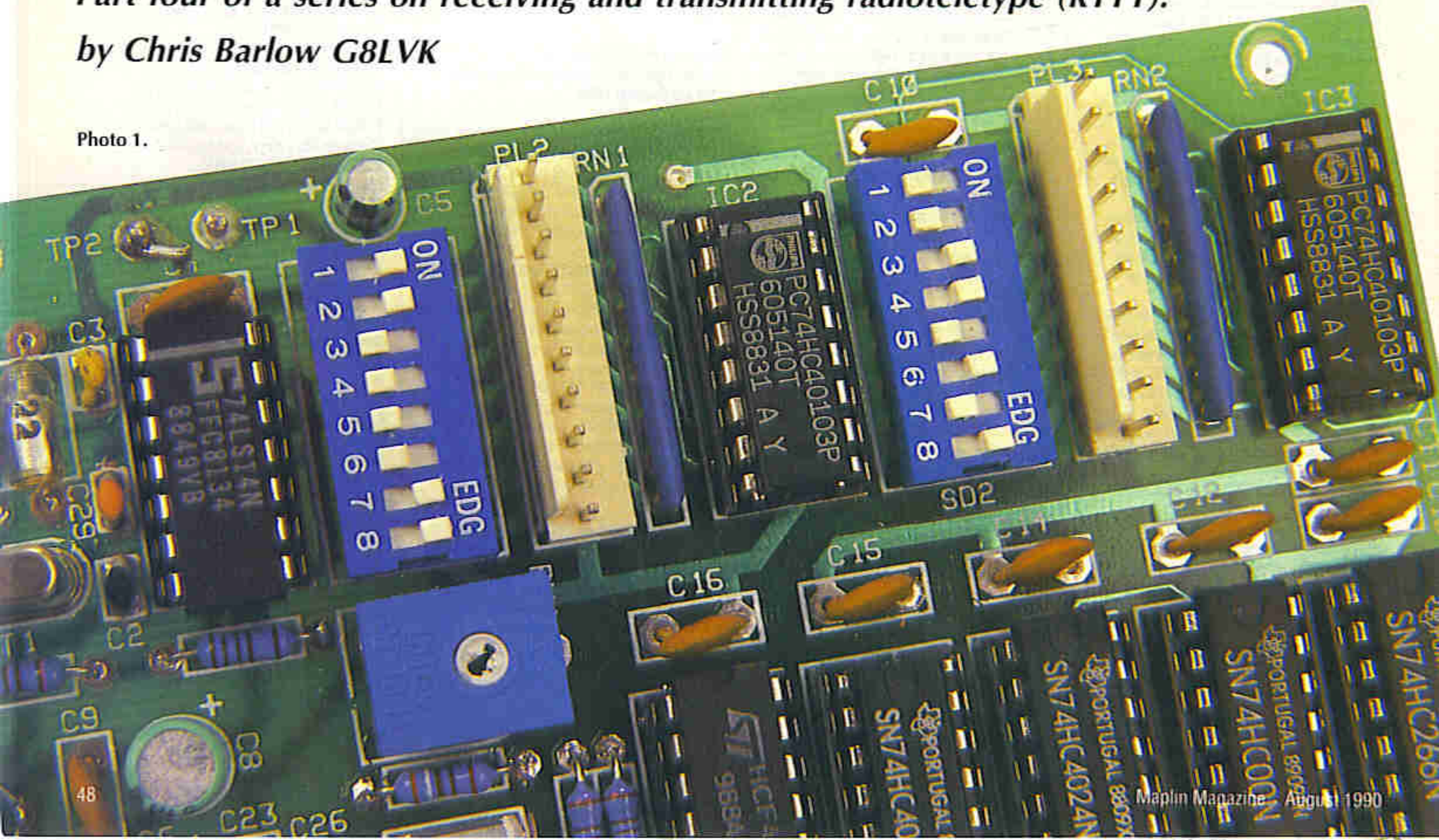
Specification of Prototype:

Clock Crystal:	*16.0MHz*	*Square Wave Output:*	*Normal and Inverse TTL*
Output Frequency:	*976.6Hz to 125kHz (255 steps)*	*Data Input:*	*TTL High (Mark)* *TTL Low (Space)*
AFSK Frequency Error:	*0.28% Maximum*	*Normal/Reverse Input:*	*TTL High (Normal)* *TTL Low (Reverse)*
Sine Wave Output:	*Fixed Level 800mV RMS (600Ω load)* *Variable Level 300mV RMS (600Ω load)*	*DC Power Input:*	*+8.5V to +14V*
Distortion:	*4% THD*	*Current Drain at 12V:*	*43mA*

Part four of a series on receiving and transmitting radioteletype (RTTY).

by Chris Barlow G8LVK

Photo 1.



Tone System kHz	Shift Hz	Standard Space Hz	Switch SD1 0 ↓ OFF 1 2 3 4 5 6 7 8 ON ↑ 1	Generated Space Hz	% Error	Standard Mark Hz	Switch SD2 0 ↓ OFF 1 2 3 4 5 6 7 8 ON ↑ 1	Generated Mark Hz	% Error
1	170	1275	1 1 0 0 0 0 1 1	1276	0.08	1445	0 0 1 1 0 1 0 1	1445	0
	425	1275	1 1 0 0 0 0 1 1	1276	0.08	1700	0 1 0 0 1 0 0 1	1701	0.06
	850	1275	1 1 0 0 0 0 1 1	1276	0.08	2125	1 0 1 0 1 1 1 0	2119	0.28
2	170	2125	1 0 1 0 1 1 1 0	2119	0.28	2295	0 0 1 1 0 1 1 0	2294	0.04
	425	2125	1 0 1 0 1 1 1 0	2119	0.28	2550	1 0 0 0 0 1 1 0	2551	0.04
	850	2125	1 0 1 0 1 1 1 0	2119	0.28	2975	1 1 0 0 1 0 1 0	2976	0.03

Frequency calculation.

Example 1 : XT1 = 16MHz or 16000000Hz
SD1 = 11000011 or Binary 195+1 = 196
XT1 ÷ SD1 = 81632.6Hz ÷64 = 1276Hz Space.

Example 2 : XT1 = 16MHz or 16000000Hz
SD2 = 00110101 or Binary 172+1 = 173
XT1 ÷ SD2 = 92485.6Hz ÷64 = 1445Hz Mark.

Table 1. RTTY AFSK frequencies

Introduction

The transmission of Radioteletype (RTTY) using Audio Frequency Shift Keying (AFSK) requires the accurate generation of two tones. This is achieved by using digital circuitry locked to a crystal controlled clock with the frequency of the tones set by two 8-way dual-in-line switches. These tones represent the logic conditions high or low, commonly referred to as mark and space tones. The frequency difference (shift) of the tones can vary considerably, but, in practice three are used; 170Hz, 425Hz and 850Hz. The AFSK generator has the ability to be set to any of these shifts by using the information given in Table 1.

Circuit Description

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

The DC power for the circuit is applied to PL1, negative (0V) to pin 1 and positive to pin 2. This supply must be within the range of 8.5V to 14V and have the correct polarity, otherwise damage will occur to the semiconductors and polarised components. The input voltage (+V1) is decoupled by C6, C7 and further decoupling is provided at regular intervals throughout the rest of the circuit. All the digital IC's are supplied from the +5V rail (+V2) produced by RG1.

The timing signals used in the circuit are derived from a master clock, IC1, referenced to a 16MHz quartz crystal XT1. Because of the basic high accuracy of this crystal no trimming capacitor is required and its operating frequency is set

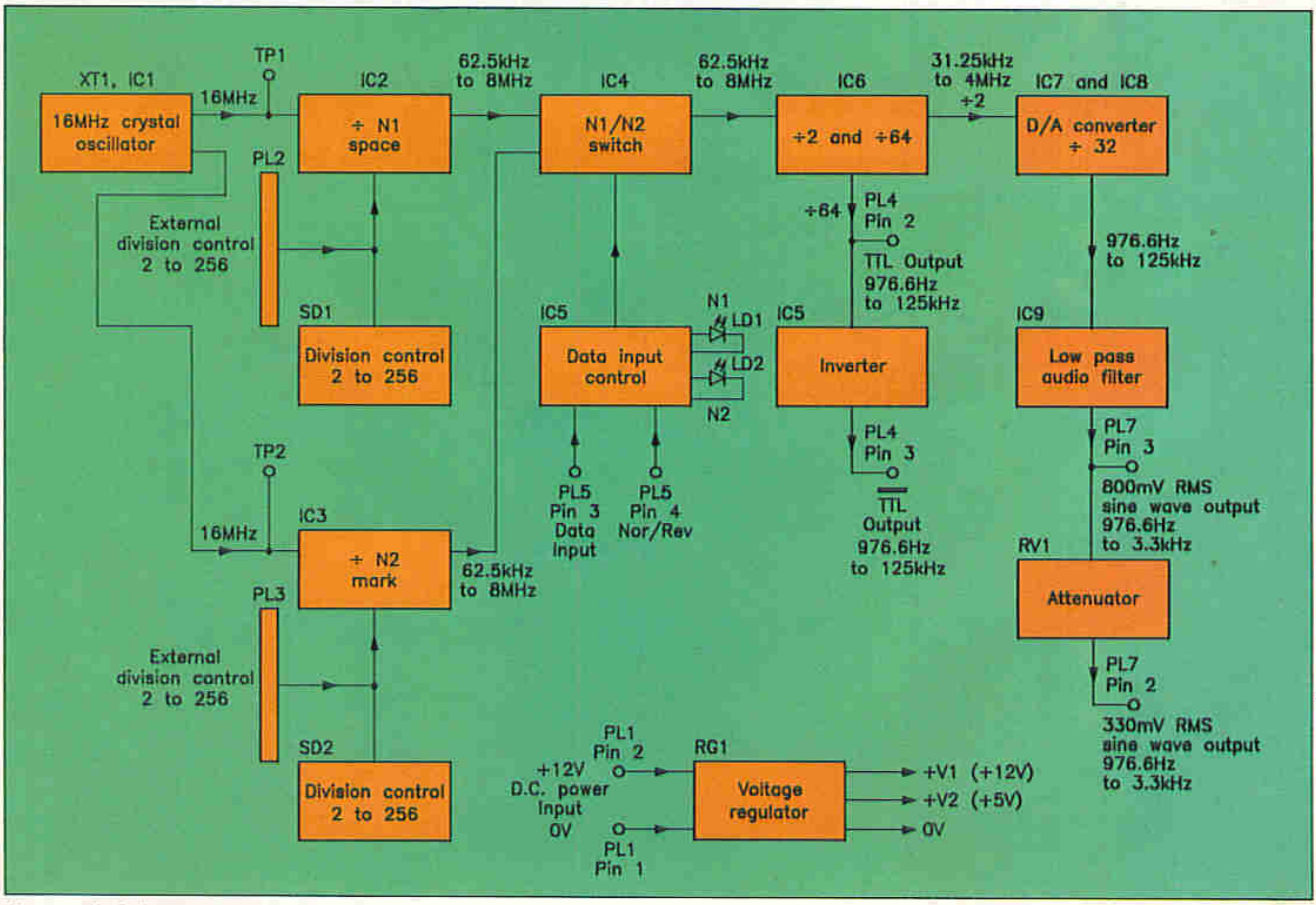


Figure 1. Block diagram

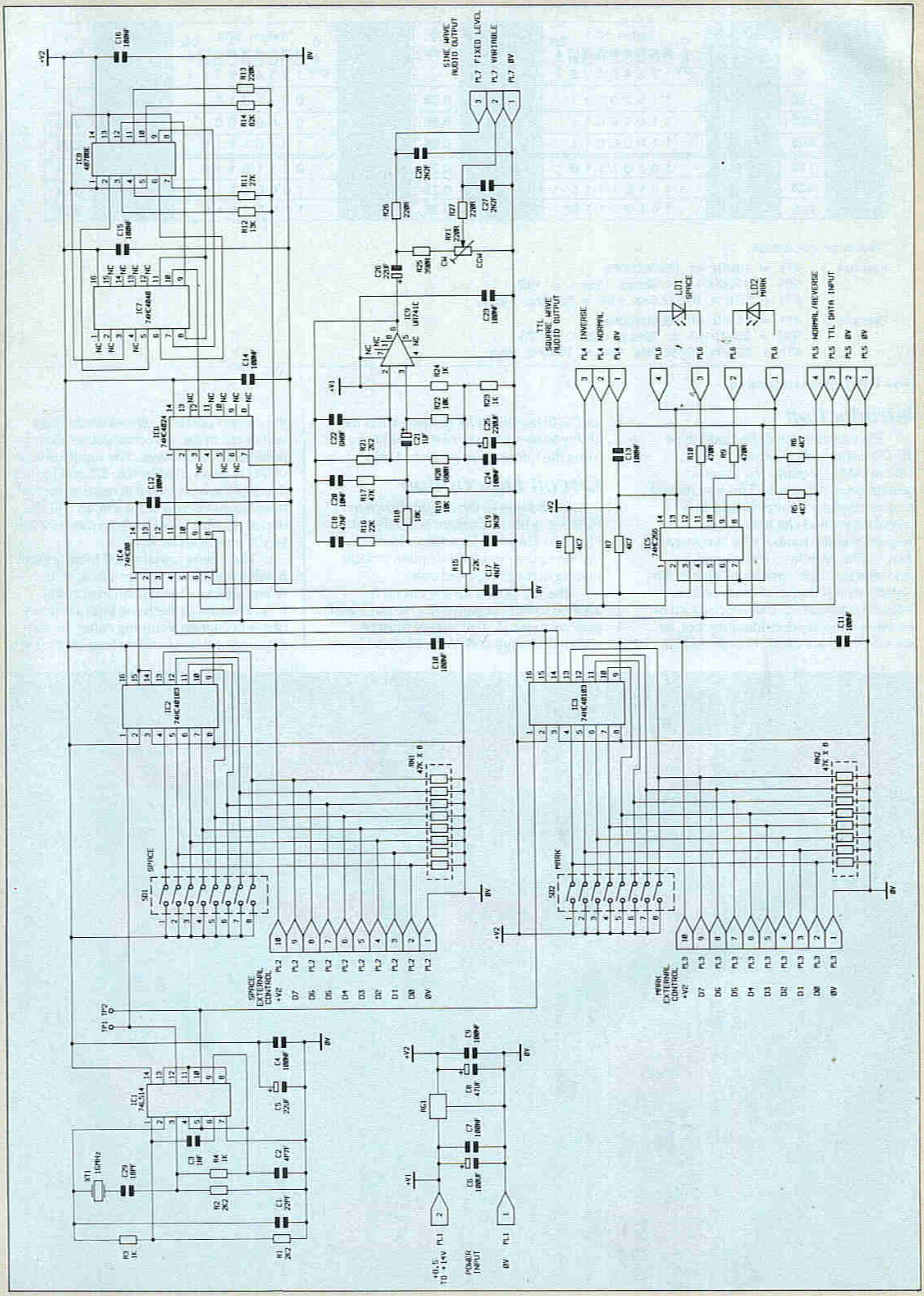
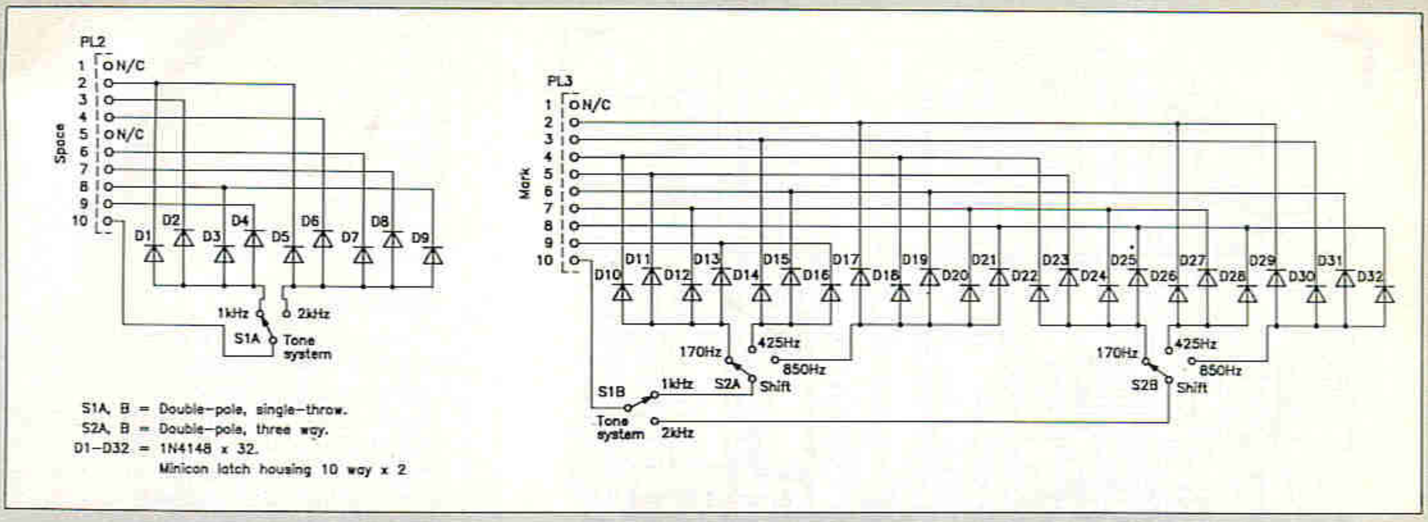


Figure 2. Circuit diagram



S1A, B = Double-pole, single-throw.
S2A, B = Double-pole, three way.
D1–D32 = 1N4148 x 32.
Minicon latch housing 10 way x 2

Figure 3. Diode switching

by C29. Two buffered 16MHz clock outputs appear at TP1 and TP2 which provide the timing signals for the programmable dividers IC2 and IC3.

The division code for IC2 and 3 is set by the 8-way dual-in-line switches SD1 (SPACE) and SD2 (MARK), or by the external control provided by PL2 (SPACE) and PL3 (MARK), see Table 1 and Figure 3. The 16MHz clock can be divided by any number from 2 to 256, this results in the generation of two independent frequencies in the range of 62.5kHz (divide by 256) to 8MHz (divide by 2).

The two frequencies are then fed to IC4 which is used to select the mark or space signal controlled by the data input stage IC5. This IC contains four exclusive NOR gates, one is used to select the normal or reverse tone condition. If the data input on PL5 pin 3 is high then the mark signal is selected. However, if PL5 pin 4 is taken low then the space signal is switched through and the reverse logic condition will apply to PL5 pin 3. Two of the remaining gates are used to drive the LED's LD1 (SPACE) and LD2 (MARK) providing a visual indication of data entering the AFSK generator.

Data controlled signals leave IC4 and enter the 7-stage ripple counter IC6 which has a number of fixed divided outputs. The divide by 64 output produces the final frequencies 976.6Hz to 125kHz as a TTL square wave on PL4 pin 2 and an inverted signal from the fourth stage of IC5 appears on pin 3. The divide by 2 output of IC6 produces frequencies from 31.25kHz to 4MHz which are fed to the digital to analogue (D/A) converter IC7 and IC8.

IC7 is a 12-stage ripple counter and IC8 is a quad exclusive OR gate. This configuration produces 16 digital codes, which are sequentially generated at the rate of the incoming signal (31.25kHz to 4MHz). Four bits of the counter feed one input of each OR gate with the fifth counter bit feeding the other input of all four gates. It is the logic state of this fifth bit that determines whether or not the four bits are to be inverted. The four bit code is converted into an analogue tone by using the resistor ladder R11 to 14. Each half cycle is constructed from 16 digital steps and as the four bits are inverted the other half cycle is generated. This has the effect of dividing the incoming signal by 32 producing the final frequencies 976.6Hz to 125kHz which are fed to the low pass filter IC9.

The frequency response of the low pass filter is shown in Figure 4 and as can be seen the 6dB roll off point is at approximately 3.3kHz. The output of IC9 is fed to PL7 pin 3 with RV1 providing an attenuated output on pin 2.

PCB Assembly

The PCB is a double-sided, plated through hole type, chosen for maximum 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 5.

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. It is usually easier to start with the smaller components, such as the resistors and after fitting the preset RV1 set it to the half way position. When installing the two SIL resistor networks RN1 and RN2 ensure that the end with the dot is positioned close to the circuit reference markings (RN1, RN2), see Photograph 1.

Next mount the ceramic, polystyrene, polylayer and electrolytic capacitors. The polarity for the electrolytic capacitors is shown by a plus sign (+) matching that on the PCB legend. However, on most capacitors the polarity is designated by a negative symbol (–), in which case the lead nearest this symbol goes away from the positive sign on the legend. When fitting the crystal XT1 ensure that you don't over heat it, while making sure that it is firmly on the surface of the board.

When fitting the IC sockets ensure that you install the appropriate one at each position, matching the notch with the block on the legend. *Do not* install IC

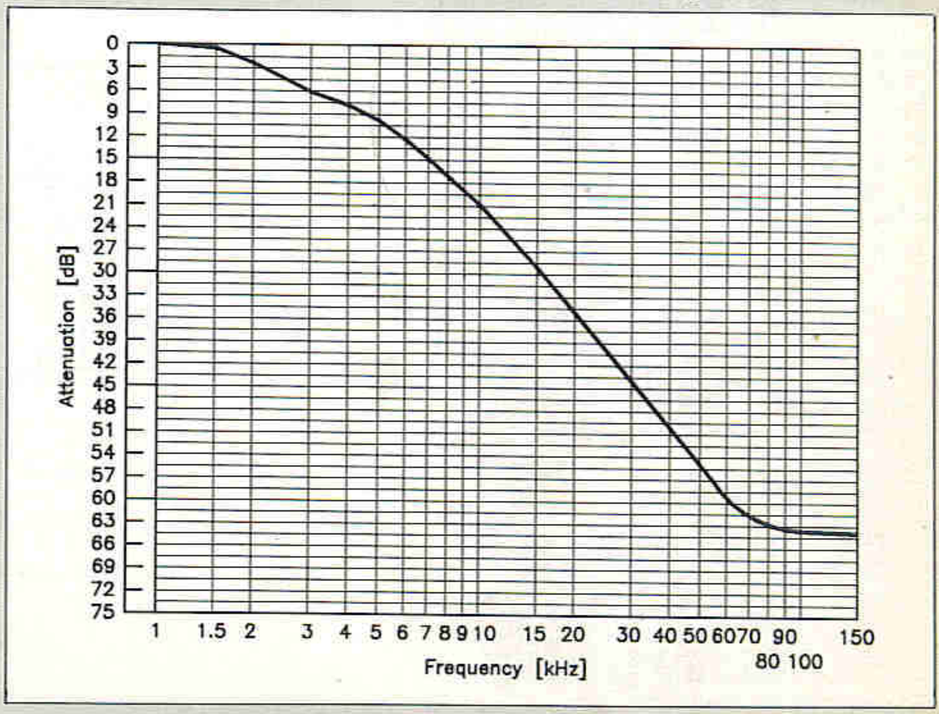


Figure 4. Low pass filter response

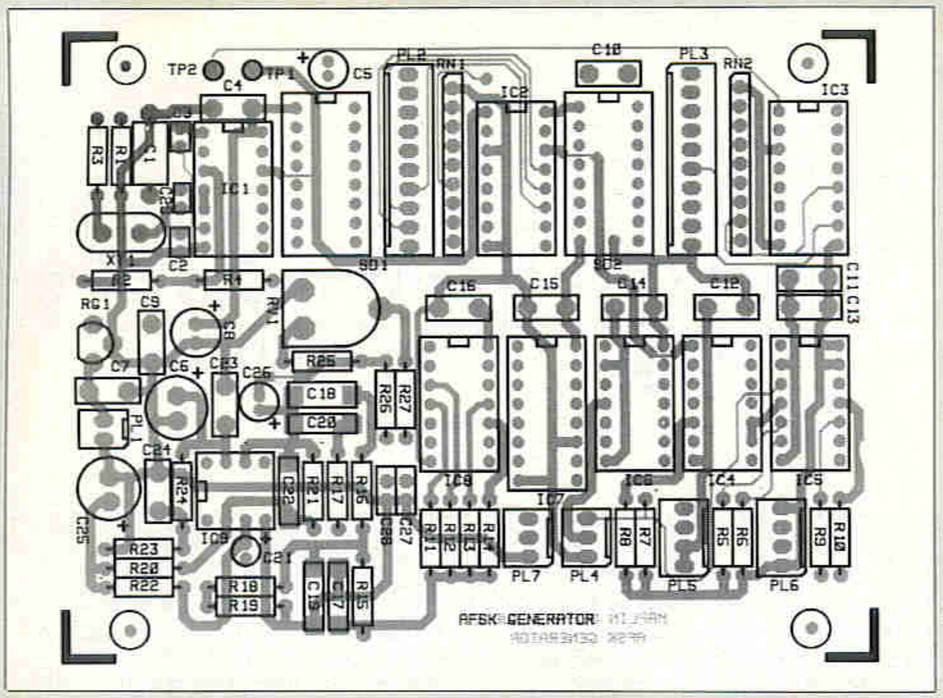


Figure 5. Layout of the PCB

sockets at SD1, SD2 and *do not* fit the IC's until they are called for during the testing procedure. Fit the eight-way DIL switches at SD1 and SD2.

Finally install the voltage regulator RG1, matching its case to its outline on the legend. This completes the assembly of the circuit board 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 PCB does not have any trimmed component leads standing proud by more than 3mm, as this may result in a short circuit. Further information on soldering and assembly techniques can be found in the 'Constructors Guide' included in the kit.

Final Assembly

No specific box has been designated for the project as your finished RTTY unit could contain several different PCB's. However, the single board prototype fitted nicely in to an instrument case type 3501, stock code YN32K.

The choice of connectors for the audio, power and data lines is entirely up to you. However, it is good practice not to use the same type of connector for two or more different functions, i.e. DATA and POWER input.

CAUTION, when installing the PCB assembly remember to use some form of spacer between its soldered side and the inside surface of the case, this is vital if you are using a metal chassis or box.

Once you have completed the mechanical assembly of the unit you should check your work very carefully before proceeding to the wiring stage.

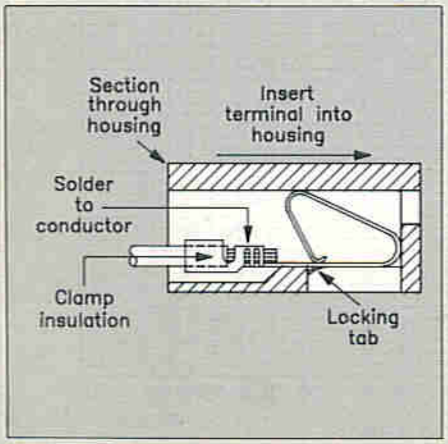


Figure 6. Fitting and inserting the Minicon terminals

Wiring

The wire connections to the PCB are made using 'Minicon' connectors and the method of installing them is shown in Figure 6. No specific colour has been designated for each wire connection, however the use of coloured hook-up wire will make it easier to trace separate connections to off-board components, just in case there is a fault in any part of the circuit. A wiring diagram showing all the interconnections is given in Figure 7.

Testing

The DC tests can be made with a minimum of equipment. You will need a multimeter and a regulated +12V DC power supply capable of providing at least 100mA. 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. Before commencing the tests double check that none of the IC's have been fitted and all the switches of SD1, SD2 are set to the OFF position.

The first test is to ensure that there are no short circuits before you connect the DC supply. Set your multimeter to read OHMS on its resistance range and connect the test probes to pins 1 and 2 of PL1. With the probes either way round a reading greater than 80Ω should be obtained.

Next monitor the supply current, set your meter to read DC mA and place it in the positive line of the power supply (pin 2 of PL1). When the supply is turned on a current reading of approximately 8mA should be registered. Switch off the unit and remove your multimeter from the DC power line. Set the meter to read DC volts. Connect its positive test lead to pin 16 of IC3 and its negative lead to pin 1 of PL1. If all is well a reading of approximately +5V should be obtained. Turn off the supply and install the IC's making certain that all

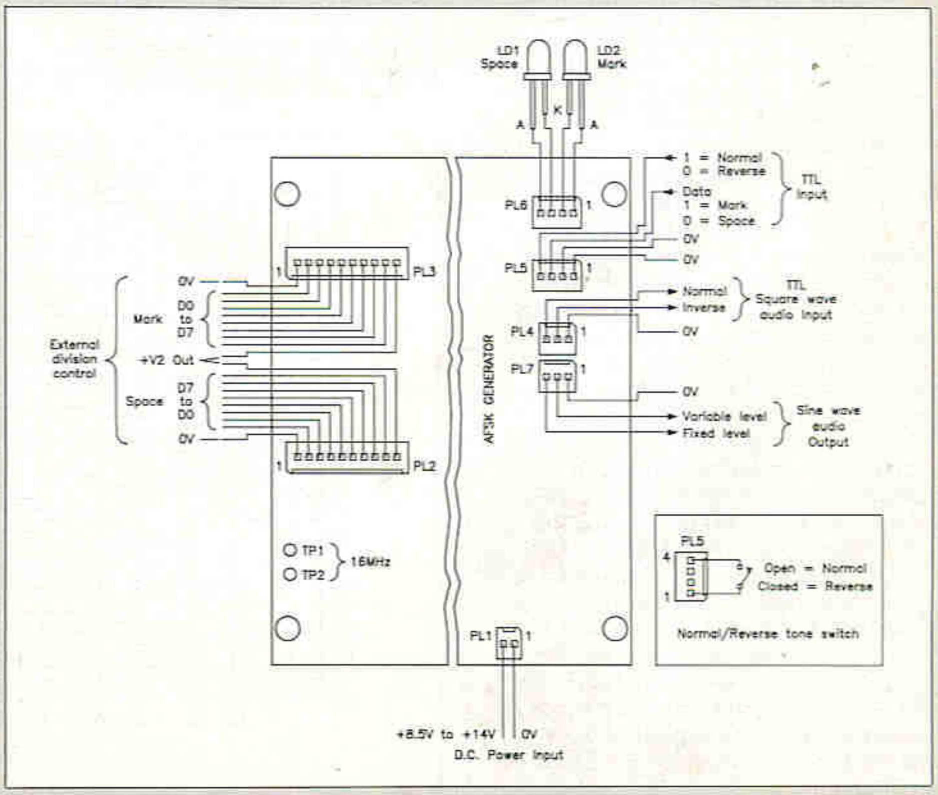


Figure 7. Wiring

the pins go into their sockets and the pin one marker is at the notched end. Power up the unit and observe the current reading which should now be approximately 40mA with LD2 on. This completes the DC testing of the AFSK generator, now disconnect the multimeter from the unit.

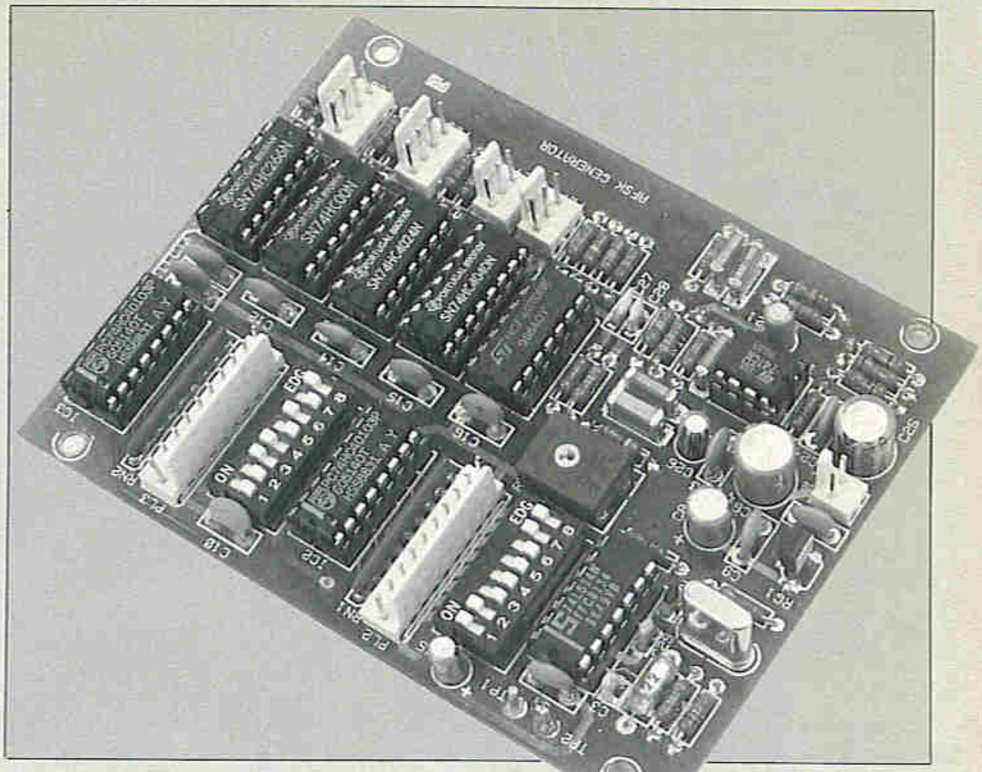
To test the logic input for data and normal/reverse tones try the following:

1. Link pins 2 and 3 of PL5. LD1 (SPACE) ON and LD2 (MARK) OFF.
2. Remove link. LD1 (SPACE) OFF and LD2 (MARK) ON.
3. Link pins 1 and 4 of PL5. LD1 (SPACE) ON and LD2 (MARK) OFF.
4. Link pins 2 and 3 of PL5. LD1 (SPACE) OFF and LD2 (MARK) ON.
5. Remove all links.

To complete the testing of the unit you will need a frequency counter and an oscilloscope to take the following readings.

1. With the ground leads of the probes to pin 1 of PL7 connect your frequency counter and oscilloscope to pin 3.
2. Set SD1 and SD2 for the 1KHz tone system with a 170Hz shift, see Table 1.
3. The frequency counter should read 1445Hz and the oscilloscope should display a sine wave of approximately 3.5V peak to peak.
4. Link pins 2 and 3 of PL5. Counter should now read 1276Hz. Remove link.
5. Move the oscilloscope probe to pin 2 of PL7 and set RV1 for maximum output (fully clockwise).
6. The oscilloscope should now display a sine wave of approximately 1.3V peak to peak.
7. As RV1 is turned anticlockwise this signal should reduce.
8. Move the oscilloscope probe to pin 2 or 3 of PL4.
9. The scope should display a square wave at 5V peak to peak.
10. Repeat step 2 for all the tone shifts, see Table 1.

This completes the testing of the AFSK generator, now disconnect all test equipment from the unit.



The AFSK Generator PCB.

Using the AFSK Generator

As can be seen from Figure 8 the AFSK generator is just part of the complete RTTY system. The demodulator (stock code LM95D) which appeared in the June to July 89 issue of the magazine is required to convert the received audio tones into serial TTL data. An optional audio bandpass filter (stock code LM93D) can be added to help reject interfering signals, see the August to september 89 issue. The slow 45 or 50 baud five bit data used by RTTY is not found on all computers that have a serial I/O port. To convert this somewhat antiquated format in to one more acceptable to modern day computers the serial format translator (stock code LM94C) must be employed, signals, see the August to September 89 magazine. If your computer has an RS232 serial port then you will also require the TTL/RS232 converter (stock code LM75S) which appeared in the April to May 89 issue of the magazine. When each stage has been constructed and tested they can be put together and with the RTTY software (stock code JR40T) running on a IBM PC or clone computer the system is complete.

Amateur radio AFSK transmissions are used on the VHF and UHF bands with the 1kHz tone system set to 170Hz shift, see Table 1. If you are using the microphone input of your transmitter then you should use the variable level sine wave output (PL7 pin 2). The preset level control RV1 should then be adjusted to give a fully modulated FM signal from your transmitter. IMPORTANT! when using the external division control inputs PL2 and PL3, you must set all the switches of SD1 and SD2 to the OFF position.

If you would like to learn more about RTTY, I would recommend contacting the British Amateur Radio Teledata Group (BARTG), c/o Mrs. Pat Beedie, GW6MOJ, Ffynnonlas, Salem, Llandeilo, Dyfed SA19 7NP.

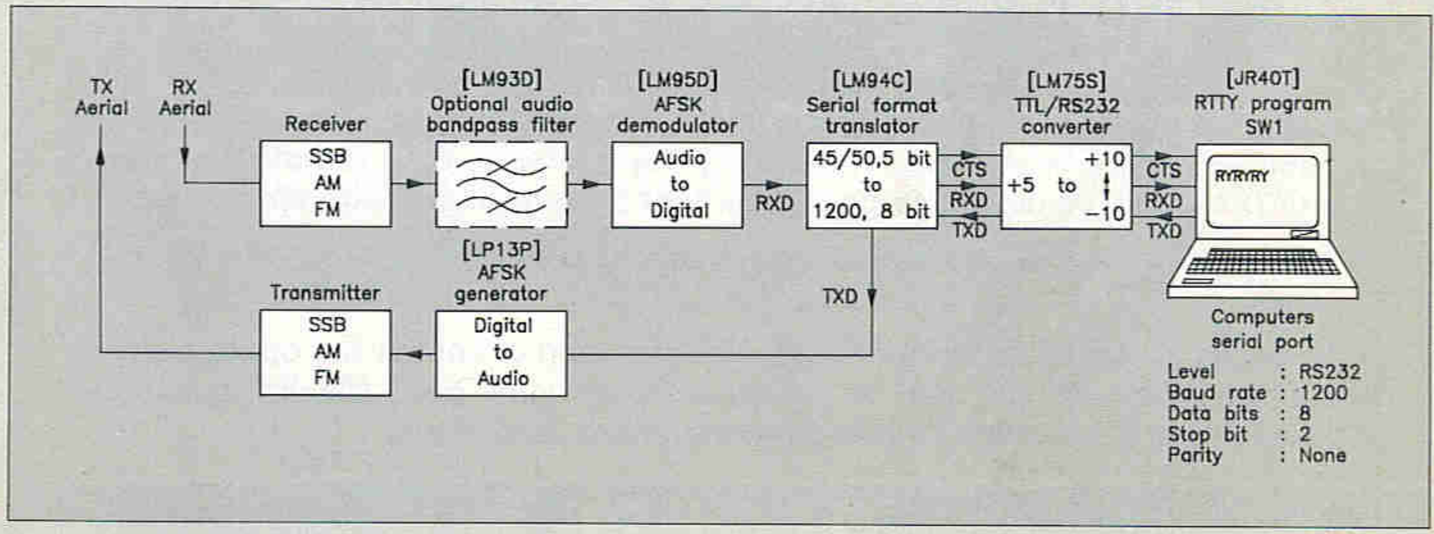


Figure 8. The complete system.

AFSK GENERATOR PARTS LIST

Resistors: All 1% 0.6W Metal Film (Unless specified)

R1,2,21	2k2	3	(M2K2)
R3,4,23,24	1k	4	(M1K)
R5,6,7,8	4k7	4	(M4K7)
R9,10	470Ω	2	(M470R)
R11	27k	1	(M27K)
R12	13k	1	(M13K)
R13	220k	1	(M220K)
R14	82k	1	(M82K)
R15,16	22k	2	(M22K)
R17	47k	1	(M47K)
R18	18k	1	(M18K)
R19,22	10k	2	(M10K)
R20	680Ω	1	(M680R)
R25	390Ω	1	(M390R)
R26,27	220Ω	2	(M220R)
RN1,2	47k SIL Resistor Network	2	(RA31J)
RV1	220Ω Hor.Encl. Preset	1	(UF98G)

Capacitors

C1	22pF Polystyrene	1	(BX24B)
C2	4p7F Ceramic	1	(WX40E)
C3	1nF Ceramic	1	(WX68Y)
C4,7,9-16,23,24	100nF Minidisc	12	(YR75S)
C5,26	22μF 16V Minelect	2	(YY36P)
C6	100μF 16V Minelect	1	(RA55K)
C8	47μF 16V Minelect	1	(YY37S)
C17	4n7F Polylayer	1	(WW26D)
C18	47nF Polylayer	1	(WW37S)
C19	3n3F Polylayer	1	(WW25C)
C20	10nF Polylayer	1	(WW29G)
C21	1μF 63V Minelect	1	(YY31J)
C22	6n8F Polylayer	1	(WW27E)
C25	220μF 10V Minelect	1	(JL06G)
C27,28	2n2F Ceramic	2	(WX72P)
C29	27pF Ceramic	1	(WX49D)

Semiconductors

IC1	74LS14	1	(YF12N)
IC2,3	74HC40103	2	(UL57N)
IC4	74HC00	1	(UB00A)
IC5	74HC266	1	(UB71N)
IC6	74HC4024	1	(UF01B)
IC7	74HC4040	1	(UF02C)
IC8	4070BE	1	(QX26D)
IC9	μA741C	1	(QL22Y)
LD1	Mini LED Green	1	(WL33L)
LD2	Mini LED Red	1	(WL32K)
RG1	μA78L05AWC	1	(QL26D)
SD1,2	DIL Switch SPST OCTL	2	(XX27E)
XT1	16MHz Crystal	1	(UJ08J)
	DIL Socket 8-Pin	1	(BL17T)
	DIL Socket 14-Pin	5	(BL18U)
	DIL Socket 16-Pin	3	(BL19V)
PL1	Minicon Latch 2-Way	1	(RK65V)
PL2,3	Minicon Latch 10-Way	2	(RK66W)
PL5,6	Minicon Latch 4-Way	2	(YW11M)
PL4,7	Minicon Latch 3-Way	2	(BX96E)
	LTCH Housing 2-Way	1	(HB59P)
	LTCH Housing 3-Way	2	(BX97F)
	LTCH Housing 4-Way	2	(HB58N)
	LTCH Housing 10-Way	2	(FY94C)
	Minicon Terminal	4 Pkts	(YW25C)
	PC Board	1	(GE24B)
	LED Clip 3mm	2	(YY39N)
	Constructors Guide	1	(XH79L)

The parts listed above are available as a kit,
but is not shown in our 1990 catalogue:
Order As LP13P (AFSK Generator) Price £19.95
The following items are also available separately:
AFSK Generator PCB **Order As GE24B Price £5.95**
74HC40103 **Order As UL57N Price £1.48**

The next issue of Electronics will contain

A free 'cure' for Indigestion ...

Take six consecutive helpings of *Electronics* the Maplin magazine, starting with the October/November issue. Read thoroughly the contents, then remove your 'free' copy of D·I·G·E·S·T, a new 32 page supplement (only available with *Electronics).*

Packed full of articles and hints, items new and old, D·I·G·E·S·T is sure to be your cure for all ills.

Great colour pages of the latest Maplin goodies, and of course the opportunity to collect the series of six, and in effect, build-up your own Maplin 'catalogue' absolutely free! It's enough to give our competition heart-burn.

D·I·G·E·S·T

ORDER COUPON

Maplin ELECTRONICS

P.O. Box 3, Rayleigh, Essex SS6 8LR.
Telephone, Credit Card Sales (0702) 554161; Enquiries (0702) 552911.
A different postal code is correctly shown on the reply paid envelopes.

In any correspondence please quote your customer number. *Date* ....

Customer No. ....

Name ....

Address ....

....

.... *Post Code* ....

IT IS MOST IMPORTANT THAT YOU INCLUDE YOUR POSTCODE

Block capital letters please. ***Keep a copy of your order.***

*Please enter catalogue page no. where item appears. If not in catalogue, write Mag for Magazine or SO for Special Offers etc. If not using 1990 catalogue, enter date of catalogue here: 19...........

Description (for your information only)	**Page***	**Order Code**					**Quantity**	**Price Each**	**£ Total**	**p**
Current Price List (Please write 1 in quantity, if required)		X	F	0	8	J		FREE	0	00
Price Change Leaflet (Please write 1 in quantity, if required)		C	A	9	9	H		FREE	0	00

Total this sheet £		
Total other sheet(s) £		
Total for goods £		
Handling charge. If total for goods between £9.25 and £10, make total £10. If total less than £9.25, add 75p.		
Deduct value of Credit Note No .... Enclose the numbered Credit Note with this order.		
Deduct value of Gift Token No. .... (Enclose Gift Token with order.)		
Please add 75p Carriage and Packing This amount must be added to each order placed.	0	75
Total £		

PHONE BEFORE 5pm FOR SAME DAY DESPATCH

Overseas customers including Channel Isles and Eire, please deduct VAT where applicable and tick this box.

Export Order ☐

Office Use Only			
DOR	CQ	CA	PO
CNC	Total		
CNM			

I authorise you to debit my credit card account for the cost of goods despatched.

Credit Card Number ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Access/American Express/Mapcard/Visa/ .... Delete as required.
Note. Goods will be despatched only if the address above is the cardholder's address.
If ordering by credit card please sign:

....

Expiry date of Credit Card..

TMS77C82 MICRO CONTROLLER

Reviewed by Tony Bricknell Part 1.

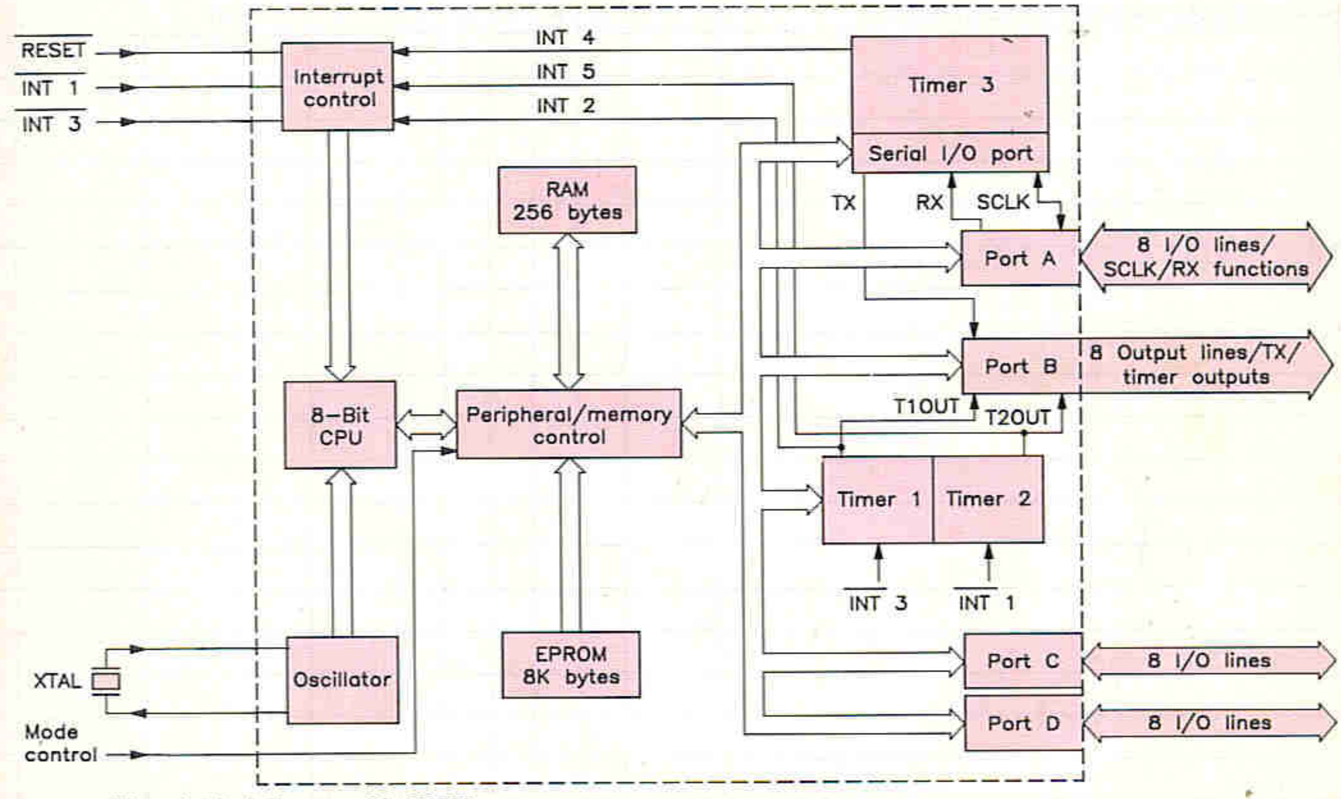


Figure 1. Block diagram of the 77C82.

Features:
- ★ CMOS technology
- ★ Low power 'sleep' modes
- ★ 8K on-chip eraseable EPROM
- ★ 256 byte on-chip RAM
- ★ 32 I/O pins
- ★ On-chip serial port
- ★ Three on-chip timers/event counters

Applications:
- ★ Security systems
- ★ Autodialers
- ★ Robotics
- ★ Bar-code readers
- ★ Trip computer for motor vehicles

		Min	Typ	Max	Unit
Supply Voltage		3	5	6	V
Oscillator frequency at 5V ± 10%		0.5		6	MHz
CLKIN duty cycle		45		55	%
Programming Supply Voltage (MC pin)		12	12.5	13	V
Operating Temperature		0		70	°C
Supply Current,					
Operating Mode	Vcc=5V, f=6MHz		16.1	24.8	mA
	Vcc=5V, f=4MHz		14.4	22.2	mA
	Vcc=5V, f=1MHz		11.2	17.2	mA
Wake-up Modes		20uA		12.5	mA
On-chip EPROM			8		Kbytes
Internal RAM			256		bytes
Interrupt Levels:					
External			2		
Total			6		
Timers/event counters:					
21-bit			2		
10-bit			1		
I/O lines:					
Bidirectional			24		
Output only			8		
Additional features			Serial Port		

Table 1. Key features and electrical characteristics of the 77C82.

I/O	SINGLE-CHIP MODE	PERIPHERAL-EXPANSION MODE	FULL-EXPANSION MODE	MICROPROCESSOR MODE
Port A	8 I/O pins A4=A4/SCLK A5=A5/RXD A6=A6/EC2 A7=A7/EC1	8 I/O pins A4=A4/SCLK A5=A5/RXD A6=A6/EC2 A7=A7/EC1	8 I/O pins A4=A4/SCLK A5=A5/RXD A6=A6/EC2 A7=A7/EC1	8 I/O pins A4=A4/SCLK A5=A5/RXD A6=A6/EC2 A7=A7/EC1
Port B	8 output pins B3=B3/TXD B1=B1/T1OUT B0=B0/T2OUT	4 output pins 4 bus control signals B3=B3/TXD B1=B1/T1OUT B0=B0/T2OUT	4 output pins 4 bus control signals B3=B3/TXD B1=B1/T1OUT B0=B0/T2OUT	4 output pins 4 bus control signals B3=B3/TXD B1=B1/T1OUT B0=B0/T2OUT
Port C	8 I/O pins	8-bit address/data bus	8-bit low address/data bus (LSB)	8-bit low address/data bus (LSB)
Port D	8 I/O pins	8 I/O pins	8-bit high address bus (MSB)	8-bit high address bus (MSB)
Total I/O Pins Available	8 output pins 24 I/O pins	4 output pins 16 I/O pins	4 output pins 8 I/O pins	4 output pins 8 I/O pins
Total Memory Pins	None	8 address/data (multiplexed) 4 memory control	16 address/data 4 memory control	16 address/data 4 memory control

Table 2. TMS77C82 port configuration.

	SINGLE-CHIP	PERIPHERAL EXPANSION	FULL EXPANSION	MICRO PROCESSOR
I/O Pins:				
Bidirectional	24	16	8	8
Output only	8	4	4	4
Expansion Bus:				
Address only lines	0	0	8	8
Multiplexed Address/Data lines	0	8	8	8
Control lines	0	4	4	4
Memory Space:				
RAM	256	256	256	256
EPROM	8192	8192	8192	0
Internal Peripheral File	28	25	23	23
External Peripheral File	0	231	233	233
External Memory	0	0	56832	65024

Table 3. I/O pins & memory space available in each mode.

The TMS77C82 is a member of the TMS7000 family of 8-bit microcomputers from Texas Instruments. The 77C82 incorporates: a central processing unit (CPU), 256 byte RAM register file, 8K byte EPROM, 32 CMOS compatible I/O pins, serial communication port, two 16-bit timers with 5-bit prescale, one 8-bit timer with 2-bit prescale, 6 interrupt levels, and external bus interface logic, all on a single 40-pin chip! .

Figure 1 shows the block diagram of the device and Table 1 shows its key features and electrical characteristics. The TMS77C82 can be programmed like any 27C64 EPROM on a wide variety of PROM programmers with the aid of an adaptor socket. The microcomputer also contains an EPROM integrity feature called the R bit, which may be used to disable all external access to the EPROM.

The 16-bit timers, with their associated 5-bit prescale, 16-bit capture latch, and timer outputs, simplify A/D conversions, pulse width measurements and other time-critical application designs. For real-time applications where accuracy over long periods is essential, the Timer 1 output may be cascaded into the Timer 2 input to effectively form one 42-bit timer.

Where power consumption is critical, the TMS77C82 can idle selectable sections of the microcomputer (e.g. Timer 1, Timer 2, or UART) and use power only where needed. Also, the entire processor can be halted while retaining the 256 bytes of internal RAM.

With all these facilities on a single chip, the TMS77C82 is able to replace large quantities of logic IC's, resulting in greater flexibility of use, smaller PCB's, lower cost etc. Many complex projects previously 'scrapped' because of their complexity, cost and size can now be retrieved from the rubbish bin and redesigned using the TMS77C82.

On-Chip RAM and Registers

The 77C82 has a 64K byte maximum memory address space. On-chip and off-chip memory address space varies according to the particular mode selected.

On-chip RAM is called the ***Register File.*** The 256 bytes of RAM are treated as registers R0-R255. These are located in lower memory from >0000 to >00FF. The first two registers, R0 and R1, are also referred to as Register A and Register B, respectively. Several instructions use Register A or B implicitly as either the source or destination register to save memory and increase execution speed.

The ***Peripheral File*** is mapped into locations >0100 to >01FF, which are referred to as P0 – P255. These peripheral file locations contain the 8-bit registers, used for interrupt control, parallel I/O ports, timer control, memory-expansion control, and serial port control.

The ***Stack Pointer*** is an 8-bit CPU register that contains the address in memory of the last used stack location. Most CPU's need to have access to an area of RAM which facilitates temporary storage of data. This area of RAM is called

Address	SINGLE-CHIP	PERIPHERAL EXPANSION	FULL EXPANSION	MICROPROCESSOR
>0000	REGISTER FILE			
>0100	ON-CHIP PERIPHERALS (TIMERS, INTERRUPTS, I/O PORTS, SERIAL PORT)			
>011C	NOT AVAILABLE	PERIPHERAL EXPANSION		
>0200			MEMORY EXPANSION	
>E000	ON-CHIP PROGRAM EPROM, 8K BYTES			
>FFFF				
	SINGLE-CHIP	PERIPHERAL EXPANSION	FULL EXPANSION	MICROPROCESSOR

Table 4. Memory map for each expansion mode.

			SINGLE-CHIP	PERIPHERAL EXPANSION	FULL EXPANSION	MICRO PROCESSOR
P0	>0100	IOCNT0	I/O Control register 0			
P1	>0101	IOCNT2	I/O Control register 2			
P2	>0102	IOCNT1	I/O Control register 1			
P3	>0103	–	Reserved			
P4	>0104	APORT	Port A Data			
P5	>0105	ADDR	Port A Data-Direction Register			
P6	>0106	BPORT	Port B data	†		
P7	>0107	–	Reserved			
P8	>0108	CPORT	Port C Data	Peripheral Expansion		
P9	>0109	CDDR	Port C Data-Direction Register			
P10	>010A	DPORT	Port D Data			
P11	>010B	DDDR	Port D Data Direction Register			
P12	>010C	T1MSDATA	Timer 1 MSB decrementer reload register/MSB readout latch			
P13	>010D	T1LSDATA	Timer 1 LSB reload register/LSB decrementer value			
P14	>010E	T1CTL1	Timer 1 control register 1/MSB readout latch			
P15	>010F	T1CTL0	Timer 1 control register 0/LSB capture latch value			
P16	>0110	T2MSDATA	Timer 2 MSB decrementer reload register/MSB readout latch			
P17	>0111	T2LSDATA	Timer 2 LSB reload register/LSB decrementer value			
P18	>0112	T2CTL1	Timer 2 control register 1/MSB readout latch			
P19	>0113	T2CTL0	Timer 2 control register 0/LSB capture latch value			
P20	>0114	SMODE	Serial port mode control register			
P21	>0115	SCTL0	Serial port control register 0			
P22	>0116	SSTAT	Serial port Status Register			
P23	>0117	T3DATA	Timer 3 reload register/decrementer value			
P24	>0118	SCTL1	Serial port control register 1			
P25	>0119	RXBUF	Receiver buffer			
P26	>011A	TXBUF	Transmitter buffer			
P27-P35	>011B->0123		Reserved			
P36-P255	>0124->01FF		Not available	Peripheral Expansion		

† In expansion modes, Port B is referenced in a special manner.

Table 5. Peripheral memory map for each expansion mode.

INTERRUPT	EXTERNAL/INTERNAL	SOURCE	PRIORITY	VECTOR MSB	ADDRESS LSB
RESET	E	RESET pin low	Immediate (highest priority)	>FFFE	>FFFF
INT1	E	INT1 pin active†	Priority 1	>FFFC	>FFFD
INT2	E/I	Timer/Event counter 1 countdown past 0	Priority 2	>FFFA	>FFFB
INT3	E	INT3 pin active†	Priority 3	>FFF8	>FFF9
INT4	I	RX Buffer Loaded, or TX Buffer Empty, or Timer 3 countdown past 0	Priority 4	>FFF6	>FFF7
INT5	E/I	Timer/Event counter 2 countdown thru 0	Priority 5	>FFF4	>FFF5

† The external interrupts on the TMS77C82 device can be programmed for level and sense detection.

Table 6. Interrupt summary.

the 'Stack'. The stack operates on a last-in, first-out (LIFO) basis and is physically located in the on-chip RAM.

The ***Status Register*** is an 8-bit CPU register that contains three conditional status bits – carry (C), sign (N), zero (Z) – and a global interrupt enable bit (I). The C, N, and Z bits are used for arithmetic operations, bit rotating, and conditional branching. During reset all bits in the status register are cleared. During other interrupts, the status register is saved on the stack and can be accessed via the PUSHST and POPST instructions.

On-Chip General Purpose I/O Ports

The TMS77C82 has 32 I/O pins organised as four 8-bit parallel ports A,B,C, and D.

Port A

Is a fully bidirectional I/O port. However, pins A5/RXD and A4/SCLK serve as the serial data receive pin and serial clock, respectively, when the serial port is used. Pins A6/EC2 and A7/EC1 may be used to clock the on-chip timer/event counters, Timer 2 and Timer 1, respectively.

Port B

In ***Single-Chip*** mode, Port C is an 8-bit output port. Pin B3 is also the serial output line (TXD) for the serial port.

In ***all other memory modes,*** Port B is split into two parts. The lower nibble (pins B0 – B3) are general-purpose output-only pins. The most significant nibble (pins B4 – B7) contains the bus control signals: ALATCH, R/W, ENABLE, and CLKOUT.

Port C

In ***Single-Chip*** mode, Port C is an 8-bit bidirectional I/O port. Any of its eight pins may be individually programmed as an input or output line. In ***all other memory modes,*** Port C becomes a multiplexed address/data port for the off-chip memory bus. In this case, Port C provides the least significant byte of a 16-bit address, followed by eight bits of read or write data.

Port D

In ***Single Chip*** or ***Peripheral-Expansion*** mode, Port D is an 8-bit bidirectional I/O port. Any of its eight pins may be individually programmed as an input or output line under software control.

In ***Full Expansion*** and ***Micro-processor*** modes, Port D becomes a multiplexed address/data port for the off-chip memory bus. In this case, Port D provides the most significant byte of a 16-bit address.

Table 2 summarises the above information.

Memory Modes

The TMS77C82 can address up to 64K bytes. Four memory modes can be selected by a combination of software and hardware, allowing the optimisation of the on-chip versus off-chip memory for each application. These modes are Single-Chip, Peripheral Expansion, Full Expansion, and Microprocessor. The Mode

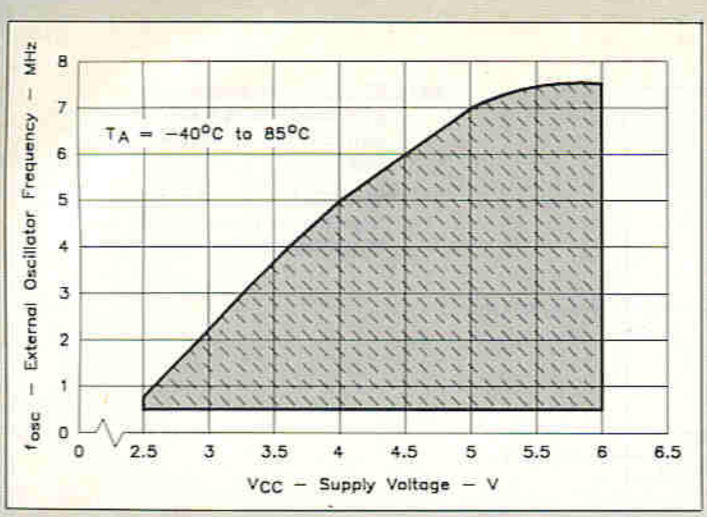


Figure 2. Operating frequency range.

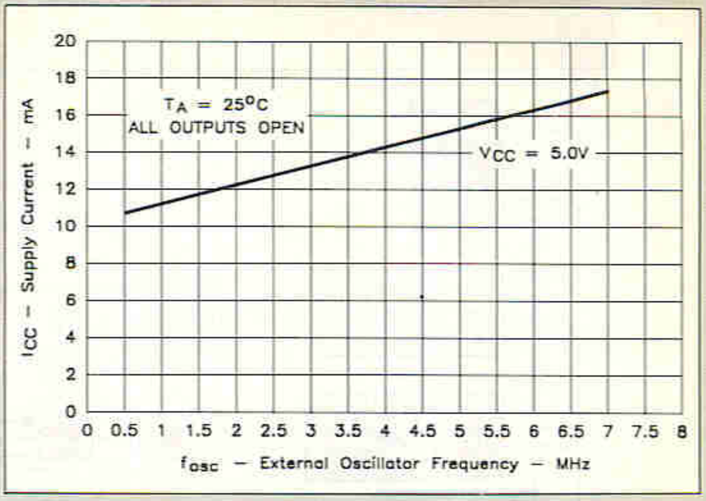


Figure 3. Operating current versus oscillator frequency.

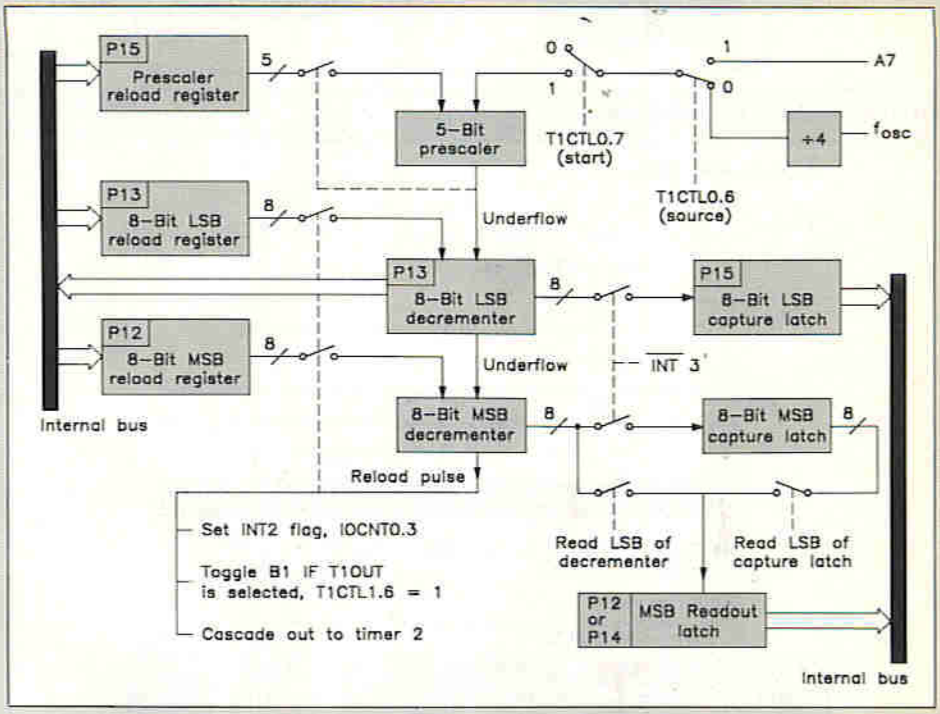


Figure 4. Timer 1 block diagram.

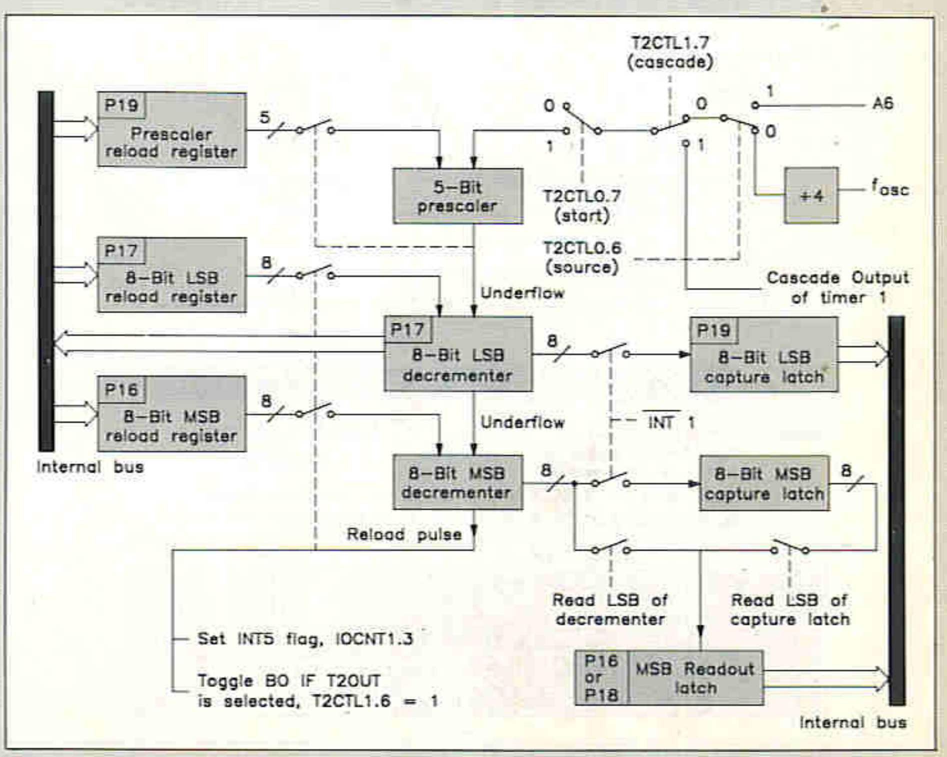


Figure 5. Timer 2 block diagram.

Control (MC) input pin forces the 77C82 into Microprocessor mode when set to V_{CC}. If the MC pin is held at V_{SS}, the remaining memory modes can be selected by bits 6 and 7 of the Peripheral File I/O Control Register P0. Table 3 shows the number of I/O pins, and the amount of external address space available in each of the different modes. Table 4 shows the memory map and Table 5, the Peripheral Memory Map for each expansion mode.

System Clock Options

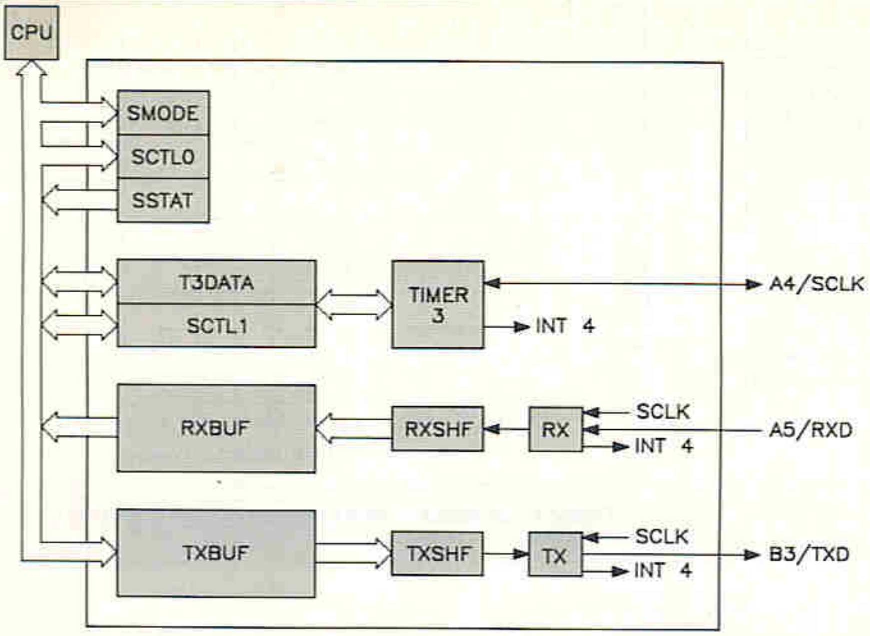
The internal state cycle period is derived from either a crystal or an external clock source. The internal clock then divides the external clock source frequency by two to produce the internal state frequency. For example, a 5MHz crystal produces an internal frequency of 2.5MHz, which drives a 400ns machine cycle. Figure 2 shows the operating frequency range of the 77C82, and Figure 3 shows typical operating current versus oscillator frequency.

CMOS Low Power Modes, Interrupts and System Reset

The TMS77C82 CMOS microcontroller can be programmed to enter low-power modes of operation when the IDLE instruction is executed. An enabled interrupt must be executed to allow the device to return to normal operation. The 77C82 device has the ability to disable the onboard timers and UART (serial port) during wake-up mode, further reducing total power consumption. One non-maskable interrupt pin is provided, RESET. This signal has the highest priority in the interrupt hierarchy. In addition to this, five separate maskable interrupts exist that can be triggered from as many as seven sources. Each interrupt has a specific priority level; if two or more interrupts occur simultaneously, they are serviced according to priority – highest first. Table 6 summarises the interrupts.

Programmable Timer/ Event Counters

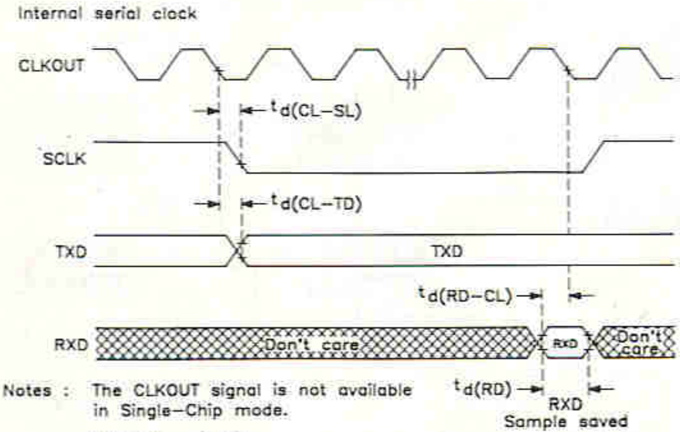
The TMS77C82 features three on-chip timers with individual start/stop



Note: **The INT4 sources are effectively wire – ORed together to generate only one INT4 Input.**

The SCLK sources are wired together to generate only one SCLK Input.

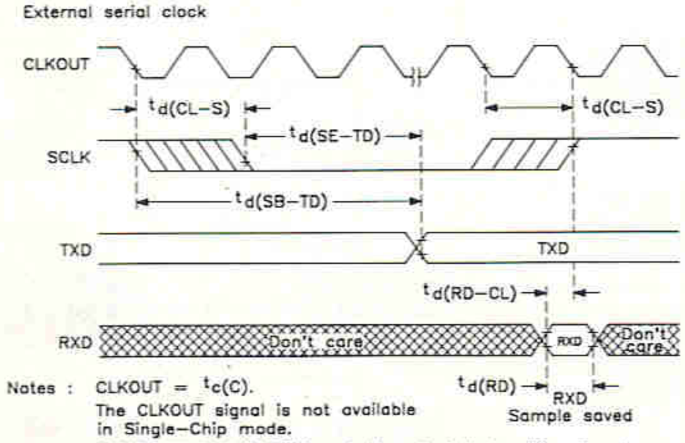
Figure 6. Serial port block diagram.



Notes : The CLKOUT signal is not available in Single–Chip mode.

CLKOUT = $t_{c(C)}$.

PARAMETER		TYP	UNIT
$t_{d(CL-SL)}$	CLKOUT low to SCLK low	1/4 $t_{c(C)}$	ns
$t_{d(CL-TD)}$	CLKOUT low to new TXD data	1/4 $t_{c(C)}$	ns
$t_{d(RD-CL)}$	RXD data valid before CLKOUT low	1/4 $t_{c(C)}$	ns
$t_{d(RD)}$	RXD data valid time	1/2 $t_{c(C)}$	ns



Notes : CLKOUT = $t_{c(C)}$.

The CLKOUT signal is not available in Single–Chip mode.

SCLK sampled: if SCLK = 1 then 0, fall transition found.

SCLK sampled: if SCLK = 0 then 1, rise transition found.

PARAMETER		TYP	UNIT
$t_{d(RD-CL)}$	RXD data valid before CLKOUT low	1/4 $t_{c(C)}$	ns
$t_{d(RD)}$	RXD data valid time	1/2 $t_{c(C)}$	ns
$t_{d(SB-TD)}$	Start of SCLK sample to new TXD data	3 1/4 $t_{c(C)}$	ns
$t_{d(SE-TD)}$	End of SCLK sample to new TXD data	2 1/4 $t_{c(C)}$	ns
$t_{d(CL-S)}$	CLKOUT low to SCLK transition	$t_{c(C)}$	ns

Figure 7. Serial port clock timing diagrams.

control bits. Timer 1 (shown in Figure 4) and Timer 2 (shown in Figure 5) consist of a 16-bit readable decrementer with a 16-bit reload register, a 16-bit capture latch, and a 5-bit prescaler with a 5-bit reload register. Timer 3 consists of an 8-bit readable decrementer with an 8-bit reload register and a 2-bit prescaler with a 2-bit reload register. Timer 3 can be used as a general purpose timer or as a baud rate generator for the serial port.

Event Counter (EC) Mode

When Timer 1 or Timer 2 is in the EC mode, pins A7 and A6 are the decrementer clock source for Timer 1 and Timer 2, respectively. The maximum clock frequency on A7 or A6 in the EC mode must not be greater than $f_{osc}/4$. The minimum pulse width must not be less than 1.25 machine cycles. Each positive transition decrements the count chain.

Timer Output Function

A timer output function exists on both Timer 1 and Timer 2 that allows the B1 and B0 outputs, respectively, to be toggled every time the timer decrements through zero.

When operating in the timer output mode, the B0 and/or B1 output cannot be changed by writing to the B port data register. The timer output feature is independent of INT2 and INT5 and, therefore, will operate with INT2 and INT5 enabled or disabled. Also, if the timer is active during the IDLE instruction, the timer output feature will continue to operate.

Serial Port

The 77C82 contains a serial port, greatly enhancing its I/O and communication capability. Including a hardware serial port on chip saves ROM code and allows much higher transmission rates than could be achieved through software. The full-duplex serial port consists of a receiver (RX), transmitter (TX), and a third timer (T3). The functional operation of the serial port is configured through software initialisation.

The serial port provides Universal Synchronous Asynchronous Receiver/Transmitter (USART) communications:

Asynchronous mode. Interfaces with many standard devices such as terminals and printers using RS232C formats.

Isosynchronous mode. Permits very high transmission rates and requires a synchronising clock signal between the receiver and transmitter.

Serial I/O mode. Can be used to expand I/O lines and to communicate with peripheral devices requiring a non-UART serial input such as A-to-D converters, display drivers, and shift registers.

The serial port also has two multi-processor protocols, compatible with the Motorola 6801 and Intel 8051. These protocols allow efficient data transfer between multiple processors. They are implemented using isosynchronous or standard asynchronous formats.

The serial port is controlled and accessed through registers in the Peripheral File. These registers are listed in Table 7. Figure 6 contains a block diagram of the serial port registers and functional blocks.

REGISTER TMS77C82	NAME	TYPE	FUNCTION
P20	SMODE	FIRST WRITE	Serial Port Mode
P21	SCTL0	READ/WRITE	Serial Port Control 0
P22	SSTAT	READ	Serial Port Status
P23	T3DATA	READ/WRITE	Timer 3 Data
P24	SCTL1	READ/WRITE	Serial Port Control 1
P25	RXBUF	READ	Receiver Buffer
P26	TXBUF	WRITE	Transmission Buffer

Table 7. Serial port registers.

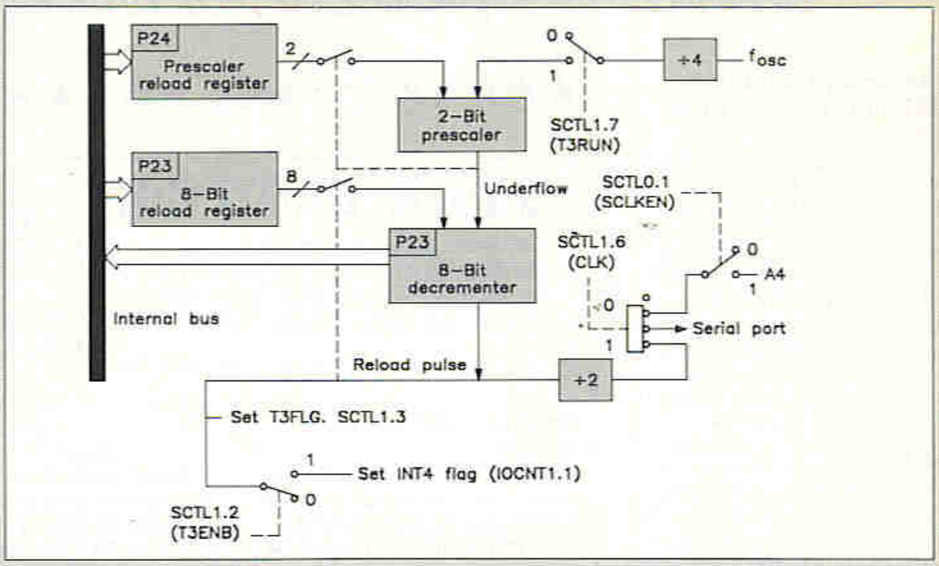


Figure 8. Timer 3 block diagram.

Timer 3

Timer 3 can be used as a general purpose timer or as the clock generator for the serial port. The Timer 3 clock source is an internal signal with the frequency equal to $f_{osc}/4$. Timer 3 consists of a 2-bit prescaler and an 8-bit counter. These are automatically reloaded from a 2-bit and an 8-bit reload register whenever a register decrements through zero.

Each time the timer decrements through zero, the Timer 3 flag and the INT4 flag are set. Timer 3 and its flags are not affected by the serial port software reset. Therefore, Timer 3 can be used independently of the serial port.

When using Timer 3 as the serial port clock source, the reload pulse output of Timer 3 goes to the serial port via a divide-by-two circuit, producing an equal mark-space ratio internal SCLK. The baud rate generated by Timer 3 is user-programmable and is determined by the value of the 2-bit prescaler and the 8-bit timer reload registers.

The equations for determining the output baud rates for both the asynchronous and isosynchronous modes are:

A synchronous Baud Rate =

$$\frac{f_{osc}}{64(PRR+1)(TRR+1)} = \frac{SCLK}{8}$$

Isosynchronous Baud Rate =

$$\frac{f_{osc}}{8(PRR+1)(TRR+1)} = SCLK$$

where: f_{osc} = frequency of the crystal or external system clock
TRR = Timer 3 decrementer reload register (P23)
PRR = Timer 3 prescale reload register (P24)
SCLK = Serial clock either input or output from the SCLK pin

The baud rate for the serial I/O mode is determined with the same equation used to determine the isosynchronous baud rate.

Figure 7 shows the serial port clock timing diagrams, and Figure 8 shows the block diagram of Timer 3.

Next Time

In the second part of this article we shall delve into the instruction set for the chip and also give details on the construction of an adaptor socket so that the TMS77C82 can be programmed by most PROM programmers.

- Do you have difficulty in getting hold of your copy of *'Electronics – The Maplin Magazine'*?
- Does your Newsagent always sell out before you can get your copy?
- Are you fed up with braving the onslaught of wind, rain and keep fit fanatics in your ceaseless quest to find a copy of your favourite electronics magazine?
- Do you say to your family and friends, "I'm just going outside, I may be gone a little while . . ."?
- Does your dog hide when you return empty handed?
- Do you resort to reading the Beano, Dandy, Viz or other well known 'comics'?

Then why not ask your friendly local newsagent to reserve or deliver every issue of 'Electronics – The Maplin Magazine'?

Here's how:

Fill out the coupon left, hand it to your newsagent and you need never miss an issue of 'Electronics – The Maplin Magazine'

ever again.

Dear Newsagent

Please reserve/deliver (delete as applicable) each issue of *'Electronics – The Maplin Magazine'* for me.

Name ....

Address ....

....

Signature ....

'Electronics – The Maplin Magazine' is published bi-monthly and is distributed through your wholesaler by: United Magazine Distribution Ltd. 1 Benwell Road, London N7 7AX. Tel: 01-700 4600.

Air your views!

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.

Beginners Should be Encouraged to Think

Dear Editor,

I think Mr Biggs' criticisms (June-July '90 issue) are totally unwarranted. This course is obviously aimed at the beginner who is just as obviously being encouraged to think for himself. There are no diagrams showing circuit track cuts in the veroboard or location of components with their polarities, so those who make up the projects included in the course, must use the theoretical diagram and make up their own boards. Even the most experienced electronic "whizzes" have to refer to pin out diagrams, for transistors, chips etc. As an ex-tutor, all I can say to you is this. Pupils must be given every encouragement to think for themselves. There are among us people who are happy to build projects of other designs, who will happily and religiously follow directions given by others. Also, there are people who will be motivated by the course to learn more and more, who will be impatient for the next part, and will be learning from other books and tapping the knowledge of the more experienced. These are the future of electronics. These people do not need the obvious explained. The course is good, the mag excellent. Keep up the good work. Finally, I must agree with the writer you haven't identified. I too look forward to 'Bob's' contributions again.

H. C. Thomas, Doncaster.

You need look no further than page 2 for the return of Bob's Mini Circuits.

STAR LETTER

This issue Mr R. J. Irvine from Renfrewshire receives the Star Letter Award of a £5 Maplin Gift Token for his letter on the SP0256 Speech Synthesiser.

Speechless!

Dear Sir,

I write to point out a possible error in the Speech Synthesiser project, published in the FEB-MAR '90 issue of 'Electronics'. The error in the article is on page 49 of the magazine where the power supply for the project is being discussed. The article states that a +5V regulated supply should be used. If this is the case, then once the 0.7V has been dropped across the protection diode D1, then only 4.3V is available for supply to the SP0256 chip. The minimum working voltage for this chip is quoted at 4.6V! The discrepancy of 0.3V, certainly on the board that I built, caused the chip to perform erratically and break down after saying a few allophones. I remedied the fault by just removing the diode and replacing it with a wire link and was careful with how I connected the power supply.

Thank you for bringing this to our attention, a corrigenda has been included on the contents page. Interestingly all of the prototypes functioned without problems; however your point is perfectly valid.

Car Tachometer

Dear Sir,

It was interesting to see the re-run of the Car Tachometer in the April-May edition. With the increasing number of cars being fitted with electronic ignition, what a pity it has not been altered to suit. Perhaps this is a project that you might consider for a future edition.

L. R. Hayes, Coulsdon, Surrey.

We have been aware of the problem of connecting the tachometer to cars with electronic ignition for some time, but unfortunately there is no simple solution/modification which is guaranteed to work with absolutely every electronic ignition system in use today. The mechanical contact breaker arrangement is virtually standard across all makes of cars, but electronic ignition systems vary an incredible amount, therefore making a universal solution a virtually impossible task. For example some systems just 'replace' the contact breakers with an 'electronic equivalent circuit' and so apply 12V to the ignition coil while other systems work on more advanced principles and apply HUNDREDS of volts to the PRIMARY of the ignition coil to provide improved ignition and combustion. If any readers are experienced with car ignition systems and have any ideas we will welcome any ideas that you may have.

Stuck at Square One

Dear Sir,

Having been interested in getting started with electronics and project building for a while I was pleased to see the initial 'Square One' article in April-May issue. I went out and purchased the necessary components and tools and set to work. First the 5V power supply – no problems, worked immediately. However having completed the 555 pulser/flasher project I could not get it to work. Not having had the necessary experience I had no way of knowing what was wrong. Then I remembered the Maplin Get You Working Service – but no joy as they only service projects on Maplin PCB's. This brings me to the million dollar question – how does a person in my position get these projects working?

Simon Ferrari, Macclesfield, Cheshire.

The following points apply to any circuit that doesn't work, but I have tailored the advice to help you get the pulser/flasher working. Check for bad (dry) solder joints and short circuits caused by stray whiskers or blobs of solder. Check that the necessary breaks in the strip-board have been made, it is easy to miss one completely or leave a tiny piece of copper in place when breaking the tracks with the track cutting tool. Check that the circuit you have built follows the circuit exactly, e.g. one end of R4 connects to the base of TR1 and the other end to IC1 pin 3 and R3. Check for correct component orientation; IC1, TR1, LED and C1. Check that the correct value components have been fitted (watch those resistor colour codes!). It is also possible that a component may have been damaged by overheating whilst soldering. Remember just one mistake can stop the circuit from working; be very thorough when checking things. If you have a multimeter, you can check to see that voltages are actually present at the appropriate points in the circuit. However this relies on you knowing what voltage should be present in the first place! (catch 22). You (and other readers) may not like the next comment but it is true: you will learn more about electronics from projects and circuits that don't work first time, than the ones that do work first time! The reason being that you will have to investigate how the circuit operates and therefore work out what voltage should be where and why components are particular values. Happy hunting!

Citizen Band Bits

Dear Sir,

Would it be possible for Maplin to stock Citizens Band Radio components (I.C.'s, transistors, spare leads, connectors, etc.) together with some test equipment (VSWR, PWR, Modulation etc. meters) and kits, projects, circuits etc. for these meters. In fact, anything to do with C.B. radio. Looking forward to your reply and the next issue of "Electronics" which I thoroughly enjoy, although some projects are a little advanced for me.

K. Thomas, Falmouth, Cornwall.

Although we do not stock all of the items you mention we do stock some of them (page numbers refer to 1990 catalogue): RF co-axial cable, page 130; UHF connectors, page 190; CB accessories, page 152; RF power meter, page 523; power/SWR meter kit, page 215. Many of the ICs used in CB equipment are very specialised and invariably each model of CB will use different IC's (Murphy's Law), therefore it would be impractical for us to supply such IC's. However we do stock many of the commonly used IC's such as audio power amplifiers, Op-amps, etc. To obtain spares for a particular CB (or any other item of consumer equipment) it is probably best to contact the manufacturer or one of their nominated spares agencies.

A COMPLETELY NEW DIMENSION IN SOUND QUALITY!

NICAM

FULLY ASSEMBLED

DECODER

- ★ Fully tested and aligned
- ★ Ready to install into almost any modern colour TV set

The Maplin NICAM 728 Decoder converts the additional digital code present† in the TV signal to a high quality stereo soundtrack with a quality similar to that of Compact Disc.

This fully working system is based upon the Toshiba NICAM chip set, and comes ready assembled.

†Currently being transmitted from Crystal Palace, Emley Moor, *Wenvoe, **Winter Hill, **Mendip and ***Black Hill.

Upgrades almost any modern colour TV set – no need to purchase a new TV set or VCR!

** From April, **From May, ***From June according to IBA schedule.*

British Digital Stereo Sound for Television

The World's most advanced high quality stereo system for land-based television!

Features

- ★ Single +12V power requirement
- ★ Automatic audio switching (Mono-Stereo-Bilingual)
- ★ British Design
- ★ Reverts to FM audio if NICAM is not present
- ★ High Quality Optimum Performance without any additional IC's
- ★ NICAM mode indicators

TELEVISION ENGINEERS

COMPLETELY ASSEMBLED FROM £60* PLUS VAT EACH

This price available to trade only, ring 0702 554171 and quote AM00A special 250 off deal reference: Electronics.
Trade: 1 off – £113, 10 off – £75, 50 off – £69.50, *250 off – £60 plus VAT each.
Normal Retail Price £129.95 (Inc. VAT) each (Order Code AM00A)

Initial availability limited – book your orders now!

ARE YOU SWITCHED ON TO NICAM

Issues 34, 35 & 36 of the Maplin Magazine contain full details of the NICAM decoder and the NICAM TV tuner projects.
Order codes:
XA34M price £1.00,
XA35Q price £1.20,
XA36P price £1.20.

★ Build-it-yourself NICAM decoder in kit form; order as LP02C £99.95

Maplin ELECTRONICS

CREDIT CARD HOTLINE

Access VISA AMERICAN EXPRESS

PHONE BEFORE 5PM FOR SAME DAY DESPATCH

0702 554161

ALL PRICES INCLUDE VAT.

All items subject to availability, all items will be on sale in our shops in Birmingham, Bristol, Leeds, Hammersmith, Edgware, Manchester, Nottingham, Newcastle-upon-Tyne, Reading, Southampton and Southend-on-Sea.

1991 BUYER'S GUIDE TO ELECTRONIC COMPONENTS

Maplin

FEATURING:
AN ELECTRONICS
CAST OF
THOUSANDS!

POWER-PACKED
WITH OVER
600 PAGES!!

STARRING
HUNDREDS OF
NEW PRODUCTS
AT SUPER
LOW PRICES!

COMING
to your local WHSMITH from
7th SEPT

PERFORMANCES DAILY
At your local branch
of WHSMITH
ONLY £2.45

Order you copy of the New MAPLIN Catalogue on sale September

Pick up a copy from any WHSMITH for just £2.45 or post this coupon now to receive your copy for just £2.45 + 50p p&p. If you live outside the U.K. send £4.85 or 20 International Reply Coupons. I enclose £2.95.

Name

Address

Post Code

Send to Maplin Electronics,
P.O. Box 3, Rayleigh,
Essex SS6 8LR.

MM91