'MAPLIN RANGER' 160m RECEIVER

BY GAVIN CHEESEMAN

FEATURES

- ★ Receives AM/CW/SSB Transmissions
- ★ Superheterodyne Design
- ★ Variable Frequency BFO
- ★ Frequency Coverage: 1·8 – 2·2MHz
- ★ Switched AGC Time Constant
- ★ Moving Coil S-Meter

Introduction

The 160m receiver is designed to cover a frequency range between approximately 1·8MHz and 2·2MHz and is capable of receiving both AM and CW/SSB modes. Many different services share the band, using a host of different transmission modes. Probably one of the most interesting parts of the band (and that for which the receiver was primarily designed) is the portion between 1·8MHz and 2·0MHz which is allocated for use by amateur radio operators. Other users of the band include 'ship to shore', coast stations and marine navigational beacons.

The receiver uses the superheterodyne principle in which the incoming signal is mixed with an internal local oscillator to produce an output at a much lower intermediate frequency (IF). The IF output is then amplified, filtered and demodulated to produce the final audio frequency signal which after further filtering and amplification is used to drive a loudspeaker or headphones. Although this system seems complicated at first sight it does have several significant advantages. Since all signals are converted to one common intermediate frequency, it is possible to achieve relatively sharp bandpass filter characteristics using standard fixed frequency LC filter technology. Any additional beat frequency oscillators (BFO) may be injected at the IF and require no further adjustment as the received frequency is changed. In addition there are also disadvantages. During the mixing process, other unwanted frequencies are also produced in addition to the required IF and care must be taken to ensure that these do not interfere with the wanted signal. Due to the nature of the mixer, an 'image' frequency is also converted to the IF as well as the wanted frequency. The frequency of the unwanted image is the difference of the IF and the local oscillator frequency. To avoid interference from strong stations, operating at the image frequency it is important that adequate filtering is used in the RF input stages of the receiver. In general the advantages and versatility of the superheterodyne receiver, outweigh the disadvantages.

Circuit Description

In order to illustrate the operation of the receiver, a block diagram is given in Figure 1 showing the basic stages of the circuit. Referring to Figure 2, it may be seen that the receiver is based around the LM3820 AM radio sub-system IC (IC1). This IC forms the basis of an AM superheterodyne receiver, containing the mixer and most of the necessary RF and IF amplifiers. Signals coming in from the aerial are initially filtered by T1/C6 and amplified by TR1 which is a dual gate FET. The signal is applied to gate 1 of the transistor and gate 2 is used to control the gain of the stage via RF gain control RV1. The amplified output from TR1 is filtered by C4/T2 and fed to the RF amplifier input of IC1. After further RF amplification, the signal is fed to the internal mixer, where it is mixed with the local oscillator. Variable capacitor VC1, T7 and associated circuitry determine the operating frequency of the local oscillator. The output from the mixer contains a wide range of frequencies and it is necessary to separate signals of the required intermediate frequency (IF) from the unwanted signals which are present. IF transformers T3, T4 and T5 together with associated components perform the IF filtering and the filtered signal is amplified by the internal IF amplifier of IC1. An internal AGC circuit maintains the final IF output at a set level. Capacitors C8 and C13 determine the AGC time constant and S2 allows either fast or slow AGC times to be selected.

The output from IF transformer T5 is demodulated by two different types of demodulator. Germanium diode D4 together with associated components is used to demodulate AM signals. This type of circuit is fine for standard double sideband AM stations but CW and single sideband suppressed carrier (SSB) signals need to be mixed with a local Beat Frequency Oscillator for correct demodulation. This process is carried out by IC4 which is configured as a product detector.

The BFO circuit is based around Field Effect Transistor TR2. IF oscillator coil T6 and associated components determine the frequency of oscillation. Frequency adjustment over a limited range is provided by applying the variable voltage produced by RV3 to a reverse biased diode (D3); this diode effectively acts as a varicap diode, changing the resonant frequency of the oscillator. Darlington transistor TR3 acts as a buffer, minimising the effect of components connected to the oscillator output.

Either the AM or SSB/CW mode may be selected using switch S3a. Switch S3b offsets the BFO frequency to avoid problems with oscillator breakthrough in the AM mode. The demodulated signal is fed to audio power amplifier IC3, via filtering components C26, C27 and R25. The input level to IC3 is controlled by volume control RV5. The output of the amplifier is fed to loudspeaker LS1 and via current limiting resistors R36 and R37 to headphone socket SK3. The switching is

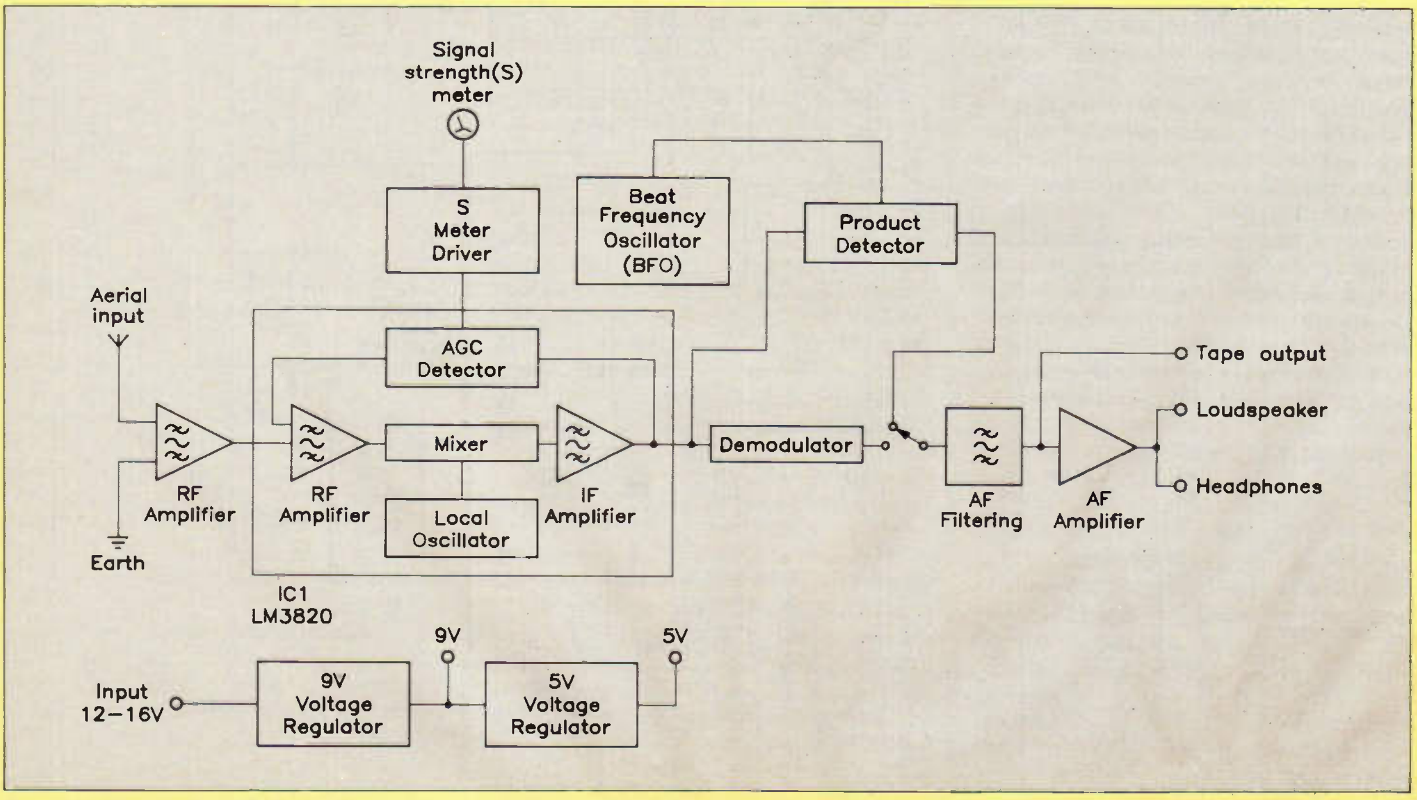


Figure 1. 160m receiver block diagram.

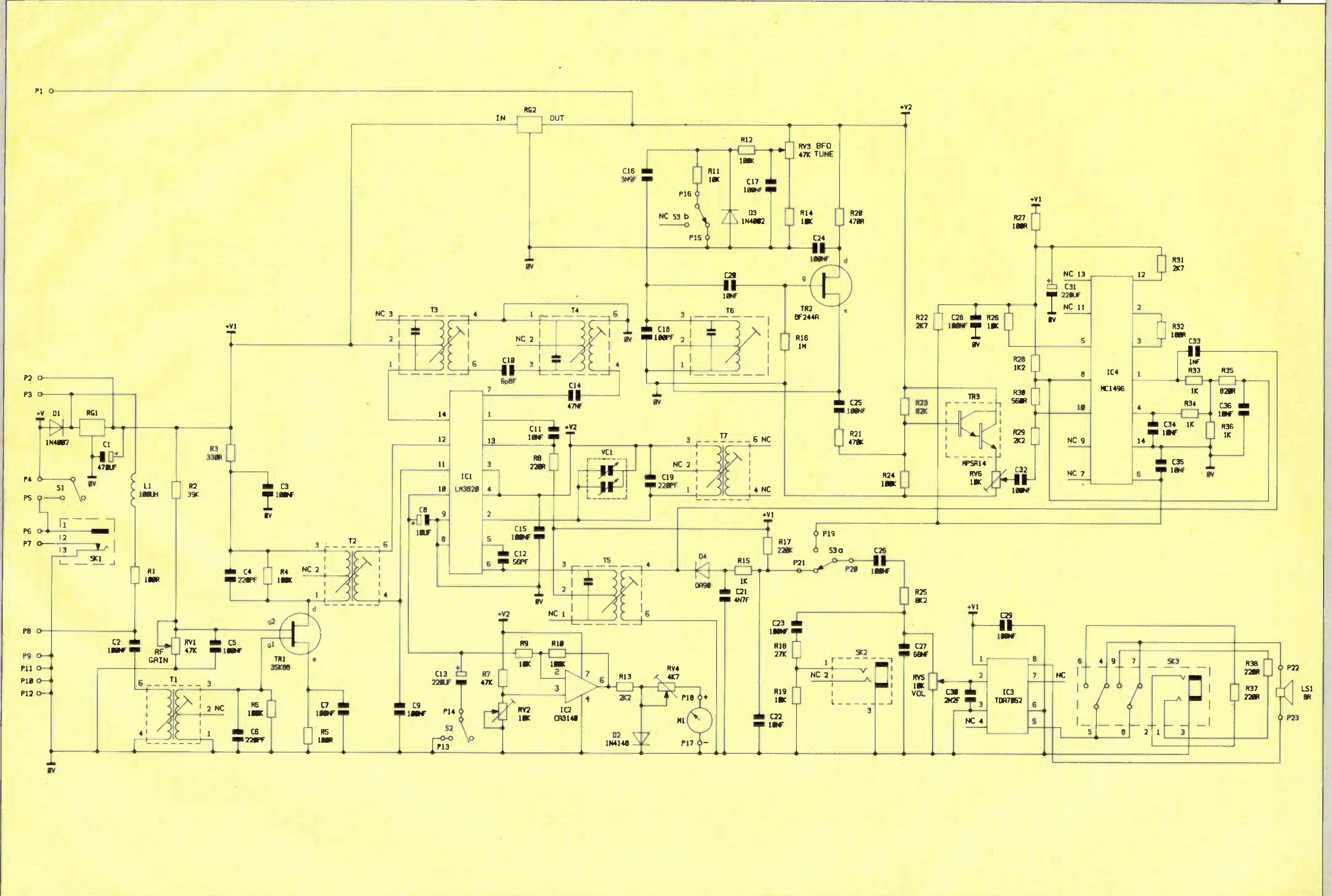


Figure 2. Circuit diagram.

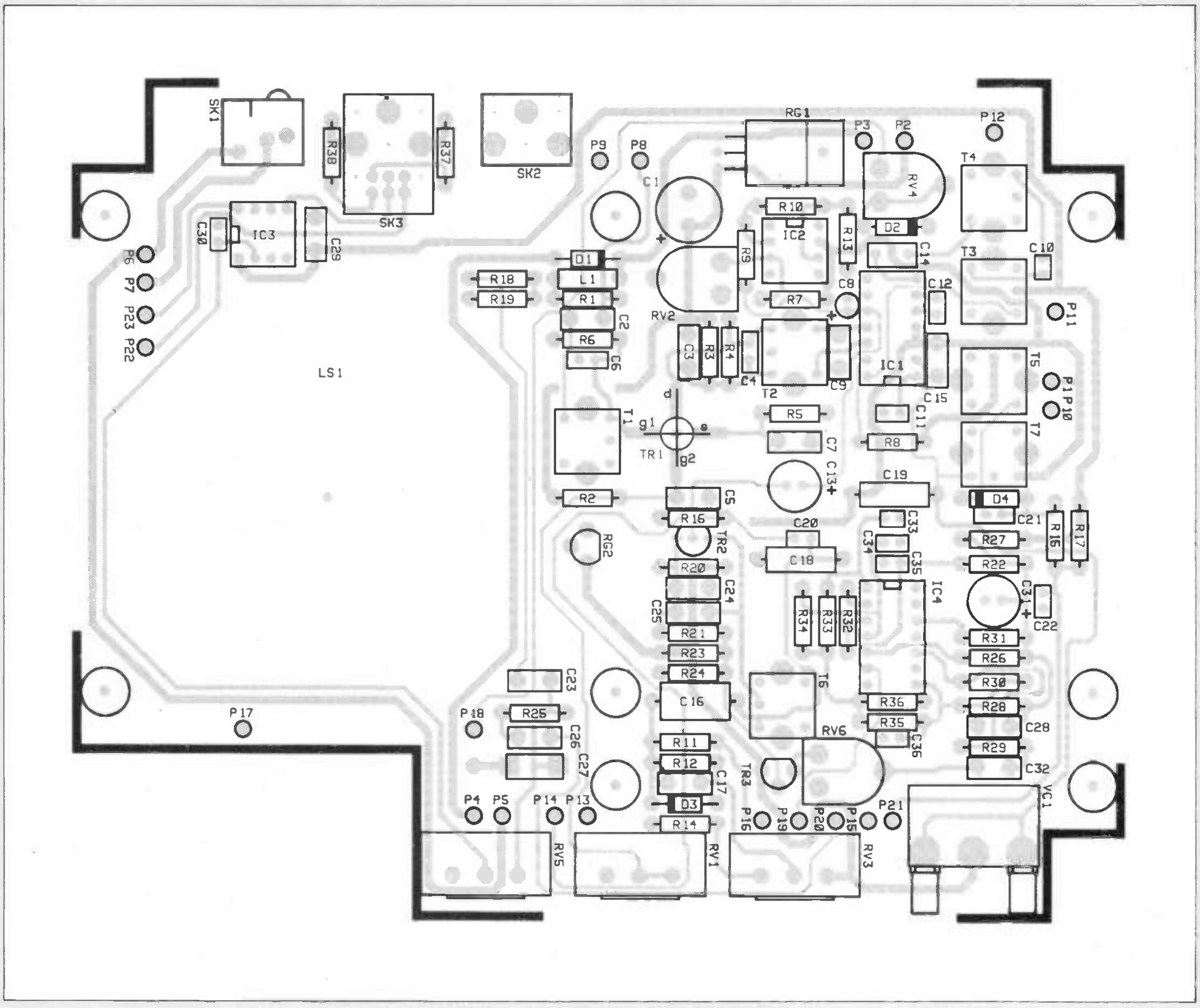


Figure 3. Legend.

arranged such that the loudspeaker is switched out of circuit when a jack plug is inserted into the socket. Mono jack socket SK2 provides a fixed amplitude low level audio output for cassette recorders etc.

The S meter circuit is based around CMOS Op-amp IC2 and is derived from the AGC voltage produced on pin 10 of IC1. Variable resistor RV2 zeros the meter and RV4 sets the meter sensitivity.

To allow the receiver to operate over a wide range of power supply voltages the circuit uses two separate regulators. RG1 is a 9V regulator and this provides the main regulated 9V supply for stable and reliable operation of the circuit. A second regulator (RG2) generates a 5V low current supply for the more critical oscillator circuitry and is also used as a reference for the S meter circuit. Although IC1 has facility for a zener stabilised supply, better stability is achieved using an IC regulator in this particular application. Diode D1 provides reverse polarity protection, preventing the power supply being connected with the wrong polarity. A low current unregulated supply is also fed to the aerial input via D1, R1 and choke L1; this is intended for operating low current equipment connected to the aerial socket such as preamplifiers or active aerials.

Construction

The receiver uses a high quality, double sided PCB with plated through holes and a screen printed legend. Insert and solder the components onto the PCB referring to the PCB legend (Figure 3). Because of the difficulty involved in removing components from this type of PCB it is essential that all components are correctly fitted the first time round. Most of the construction is straightforward and probably requires no further explanation; there are however a few points that require special attention and these are detailed below.

Before commencing construction it is recommended that you check the components against the parts list to make sure that these are correct. Start by fitting the resistors and other small components. The IC sockets should be fitted before any high profile components as these must be kept flush with the PCB. Ensure that the end of the socket marked by a notch corresponds with that shown on the PCB legend (do not fit the ICs at this stage). Install sockets SK1, SK2 and SK3 ensuring that the base of the socket is flush with the PCB. Insert and solder the PCB pins using a hot soldering iron. If the pins are heated to the correct temperature, only light pressure is required to press them into position. Once in place, the pins may then be soldered. When fitting the electrolytic capacitors it is essential that the correct polarity is observed. The negative lead of the capacitor, which is usually marked by a negative (-) symbol on the side of the case should be inserted away from the hole marked with a positive (+) symbol on the PCB legend.

Transistor TR1 is supplied in a 4 lead flat package and should be handled with care as it is a static sensitive device. The transistor is soldered onto the appropriate pads on the track side of the PCB as shown in Figure 4. As with all semiconductors, the transistor is easily damaged by heat and care should be exercised to make sure that the device is not overheated during soldering. TR2 and TR3 are inserted such that the transistor case corresponds with the outline on the legend.

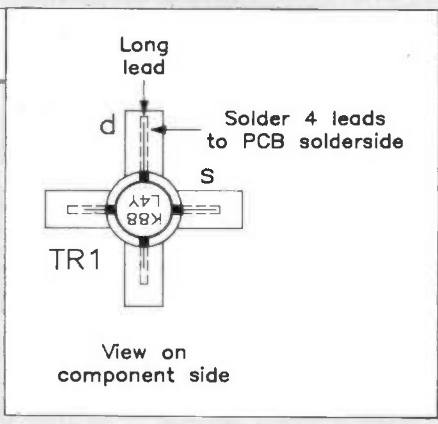


Figure 4. Mounting TR1.

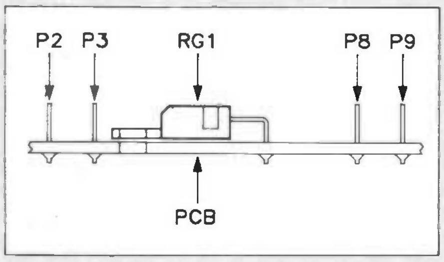


Figure 5. Mounting RG1.

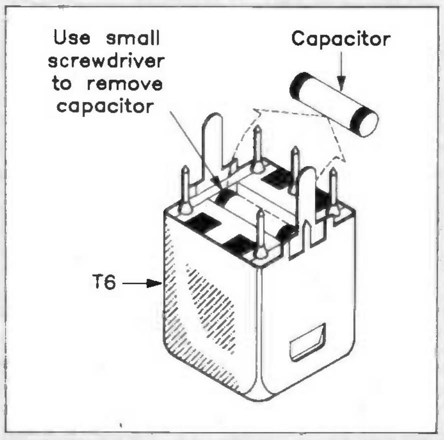


Figure 6. T6 internal capacitor removal.

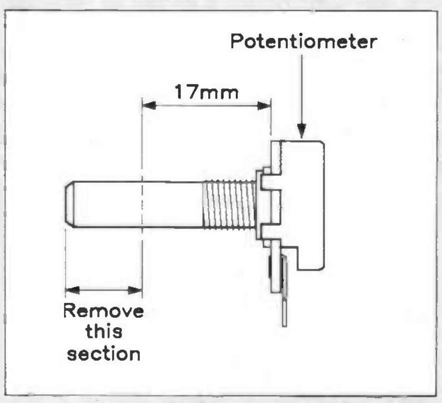


Figure 7. Cutting the potentiometer spindles.

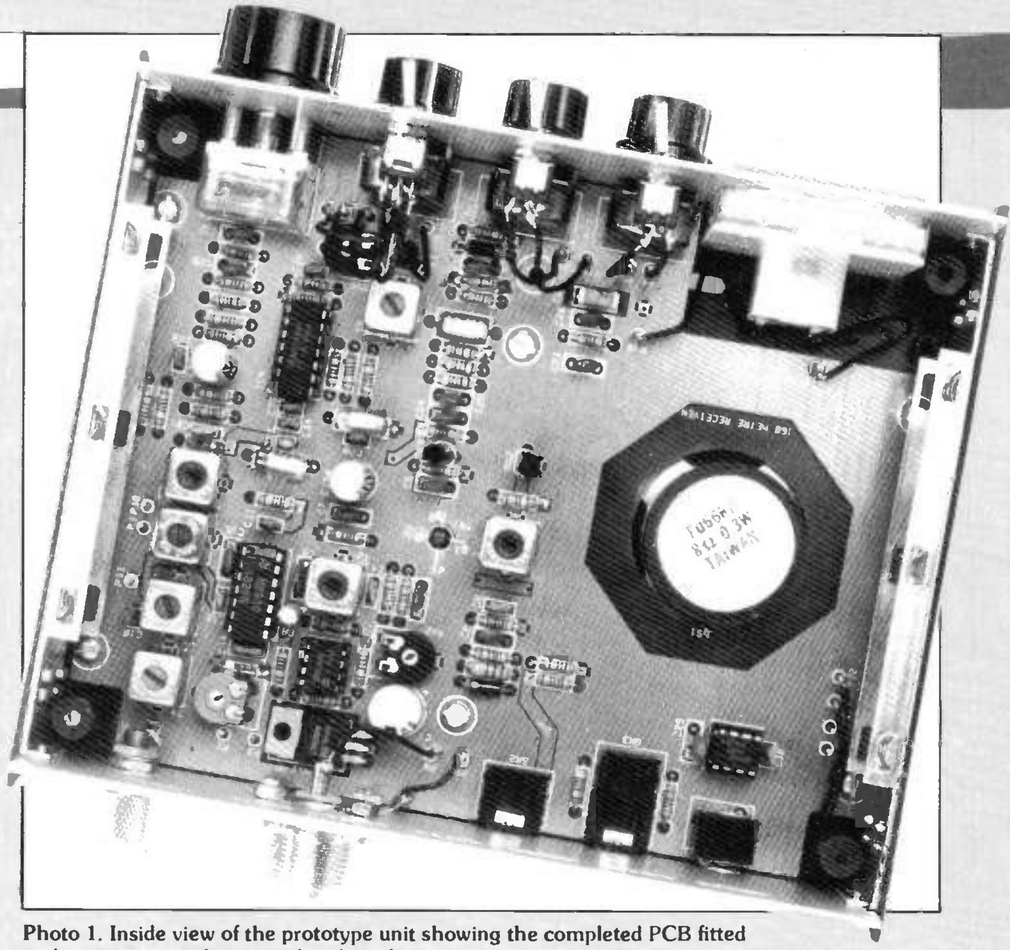


Photo 1. Inside view of the prototype unit showing the completed PCB fitted and wiring to switches, aerial and earth.

The diodes should be inserted such that the band at one end of the diode corresponds with the band on the PCB legend.

Regulator, RG1 is supplied in a 3 pin plastic package and is positioned as illustrated in Figure 5. The pins are bent, inserted into the PCB and soldered so that the regulator case lines up with the legend. It is not necessary to bolt the regulator to the PCB; however, a suitable hole is provided for those who wish to bolt the device down. RG2 is positioned such that the case corresponds with the appropriate outline on the legend.

Tuning cans T1 – T7 are fitted as indicated by the legend. T6 requires special attention as it is necessary to remove the internal capacitor from the base of the can before it is fitted onto the PCB. Figure 6 illustrates a suitable method of removing the capacitor using a small screw driver. Do not apply excessive force to the plastic base of the can as this is easily broken. Before fitting potentiometers RV1, RV3 and RV5 it is necessary to remove part of the spindle as shown in Figure 7 using a small hacksaw. When installing the potentiometers, ensure that the potentiometer pins are inserted as far into the PCB holes as possible. Next, fit VC1 such that the case is positioned approximately 3mm above the component side of the PCB (see Figure 8); this height is based on housing the receiver in the suggested box and may vary if a different box is used.

Switches S1 – S3, signal strength meter M1 and loudspeaker LS1 are wired to the appropriate PCB pins using the hook-up wire provided in the kit. Figure 9 shows a wiring diagram. After all other components have been fitted the ICs should be inserted into the appropriate IC sockets on the PCB ensuring that the notch at one end of the IC corresponds with that on the socket.

For further information on soldering and constructional techniques refer to the constructors' guide included in the kit. Before applying power to the finished receiver PCB, it is recommended that you double check your work to make sure that there are no dry joints or solder short circuits.

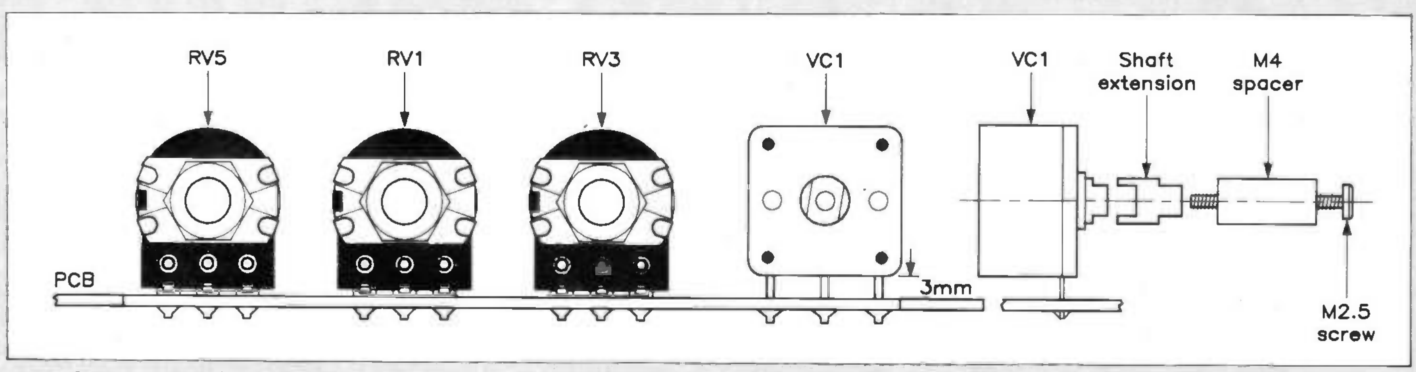


Figure 8. Fitting the PCB mounted front panel components.

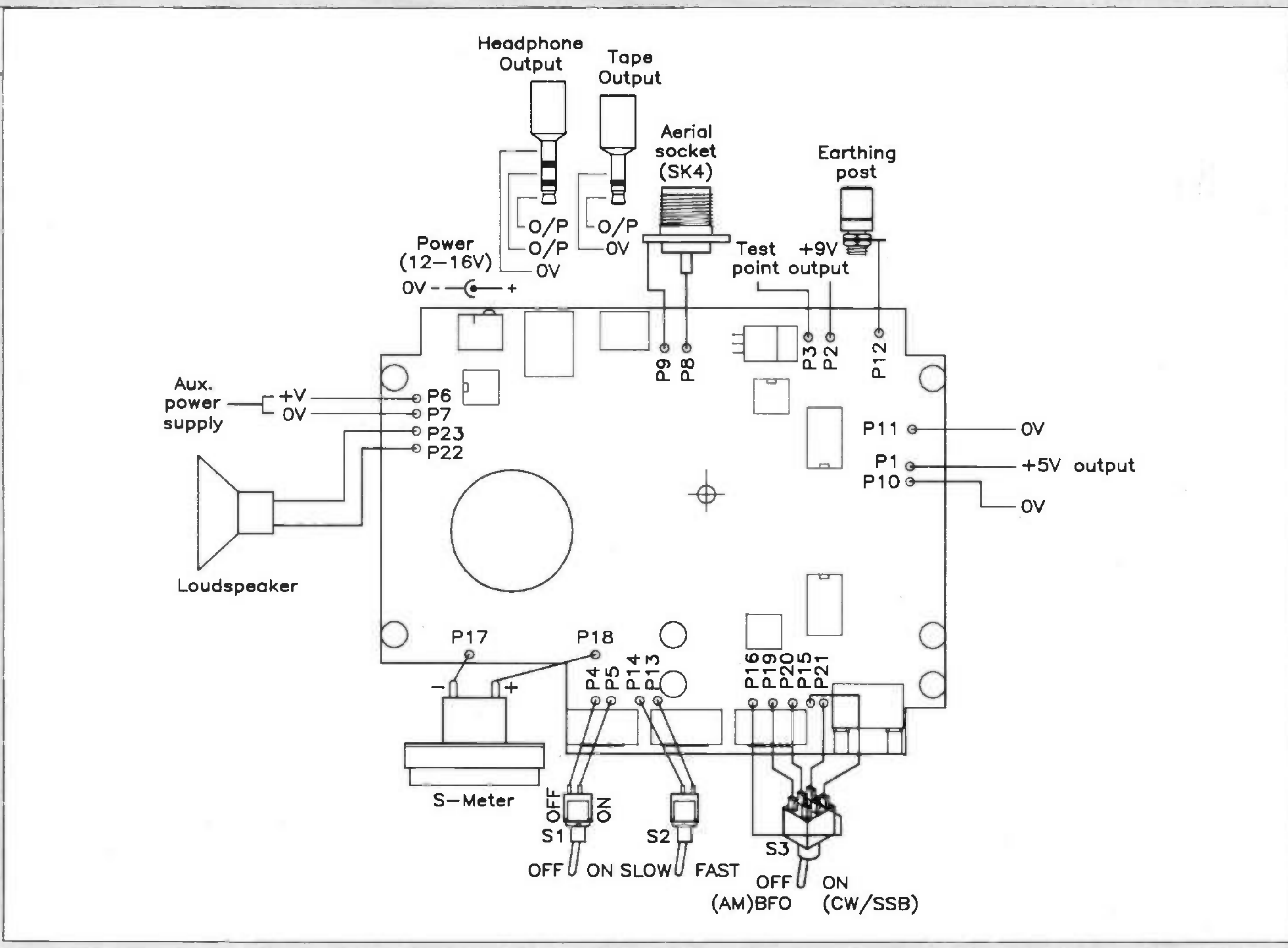


Figure 9. Wiring diagram.

Testing and Alignment

Using the superheterodyne principle, correct operation of the receiver is very much dependent on setting up the various tuned circuits correctly and on the use of the correct oscillator injection levels. These are best set up using the correct test equipment but this is not essential and the receiver can be set up by "ear".

The receiver will operate from a power supply of between 12V and 16V DC. Current consumption varies with volume, but a 300mA supply should be adequate. The power supply used for the prototype was Maplin stock code XX09K. The use of IC regulators in the design allows for relatively large fluctuations in power supply voltage without adverse results.

There are several different methods of alignment and to detail all of these would be outside the scope of this article. The two methods described below will probably be found the most useful for the home constructor:-

Alignment Using an Off Air Signal

This method entails the use of an off air signal of known frequency to align the receiver. To align the receiver using this method, a suitable aerial will be required. Initially, the IF may be approximately aligned using the internal background noise of the receiver. Apply power to the receiver and set S1 to the on position. S3 should be set to the AM position. Set preset resistor RV6 to the centre of its travel. Set volume control RV5 to maximum and adjust T3, T4 and T5 until a peak in the noise level from the loudspeaker is obtained. The noise level is relatively low and this should be done in a quiet environment or alternatively, using headphones. Once a peak has been obtained, the BFO frequency may be aligned. For this set S3 to the CW/SSB position (BFO on), set RV3 to the centre of its travel and adjust the T6 for a peak in noise. Any necessary final adjustments can be made when the remaining sections of the circuit have been aligned.

Unless a signal of known frequency is available, precise alignment of the receiver is not possible; however, the circuit may be aligned approximately by turning the ferrite core of T7 anti-clockwise until it is level with the top of the can and then turning it clockwise 4 turns. This method of frequency alignment is far from accurate but it does allow the receiver to be set approximately in the correct band. Reduce the volume to a comfortable level and connect an aerial to P8 and a suitable earth to P9 if available. Adjust T1 and T2 to obtain a relatively flat noise level over the whole band.

Alignment Using a Signal Generator

This is much preferred to the above method as it uses a signal of known frequency. The IF and RF amplifier tuned circuits may still be adjusted as described above. To align the local oscillator circuit, apply a signal between P8(i/p) and P9(0V) at a frequency of 2MHz. The amplitude of the signal should be between 1mV and 50mV peak to peak. Set VC1 to the position shown in Figure 10 and set RV1 fully anticlockwise. Adjust T7 until a strong signal is obtained. A strong unmodulated signal

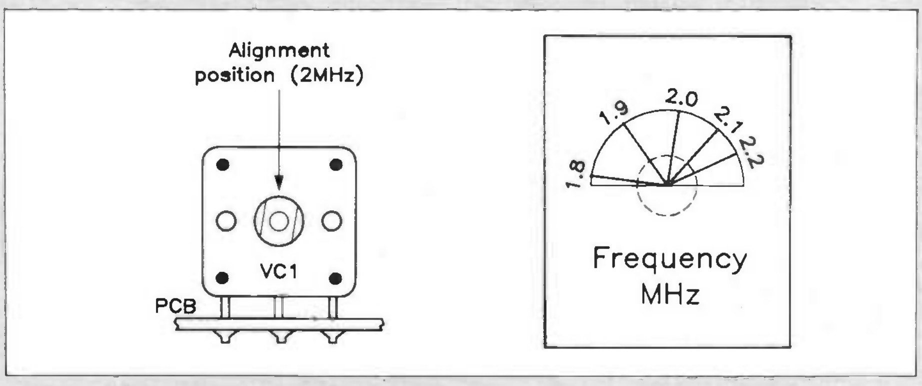


Figure 10. VC1 alignment position.

should be fully quieting in the AM mode and should produce a loud sinusoidal tone in the CW/SSB mode.

For those who wish to generate a 2MHz signal but do not possess a signal generator, Figure 11 shows the circuit diagram of a suitable low cost crystal calibrator using a 2MHz crystal. This circuit is relatively straightforward and provides a suitable reference signal with which to align the receiver.

To set up the S meter, remove any aerials/signal generator from the aerial input (P8) and set meter sensitivity preset RV3 to ¾ of its maximum travel. Adjust RV2 until the S meter indication is just fractionally above 0. When a signal is applied to the aerial input, the meter reading should then increase to indicate the relative strength of the signal. Further adjustment may be made as required.

Housing the Receiver

A suitable box in which to house the receiver is Maplin stock code YN33L. Pre-drilled front and back panels are available for the 160m receiver; these simply replace the un-drilled panels supplied with the box. The front and rear panel layouts are shown in Figure 12a and 12b respectively. For those of you who wish to drill the front panels for yourself, Figures 12c and 12d show drilling details for the front and rear panels. Loudspeaker LS1 is held in place by the PCB and the speaker magnet should protrude through the large hole provided. If required, the speaker may be glued in place using a general purpose adhesive. Figure 13 shows how to mount the front panel components. The S meter can be fixed to the front panel using glue or self adhesive pads. If adhesive is used care should be exercised to keep this away from the part of the meter that protrudes through the front panel. PCB mounting information is shown in Figure 14.

Using the Receiver

To achieve optimum performance from the 160m receiver, a reasonable aerial is a must. In general, in the 160m band, this entails the use of the longest piece of wire practically possible; this should be erected high and in the clear. Nevertheless the receiver will operate (less efficiently) with shorter aerials where space is limited. Another very important factor affecting quality of reception at this frequency is the aerial earth; this is almost as important as the aerial itself. If possible the receiver should be connected by a short length of thick cable to a suitable earthing point such as a length of copper pipe, driven into the ground. It is realised that in many situations the type of aerial installation described is just not practical but even so it is still possible to obtain reasonable performance from the receiver using much simpler installations. The design of aerials is a wide and complex subject, outside the scope of this article; however, a list of books containing useful information on radio and aerial systems is given at the end of the article.

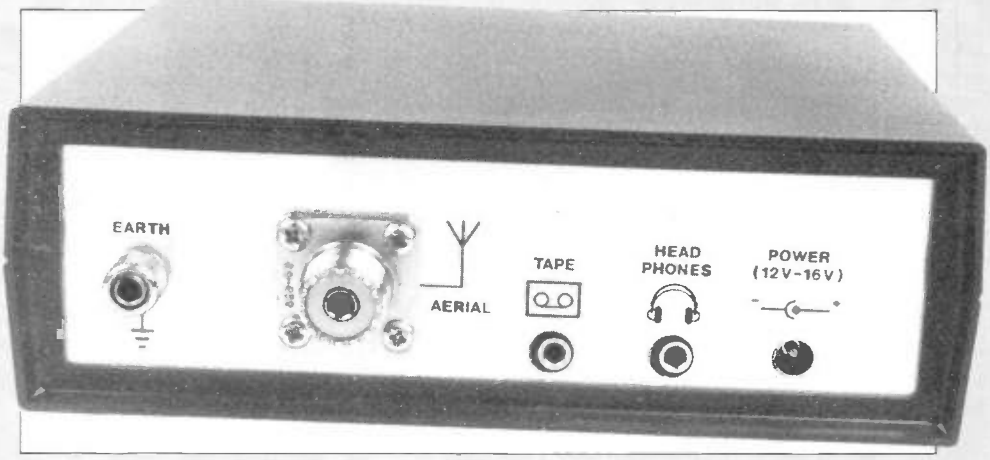
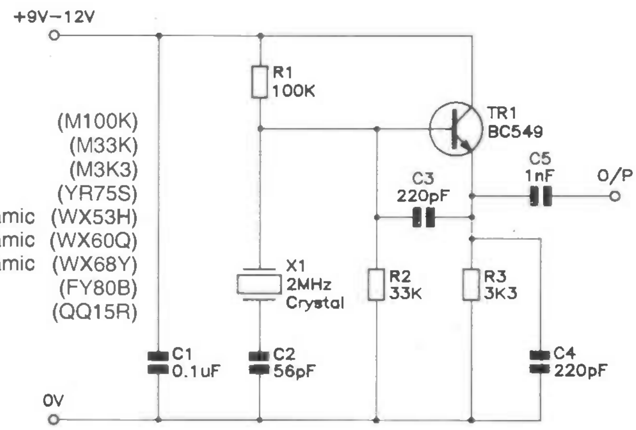


Photo 2. Rear view of the prototype unit.

Parts list

R1	100k		(M100K)
R2	33k		(M33K)
R3	3k3		(M3K3)
C1	0·1uF	Minidisc	(YR75S)
C2	56pF	Plate Ceramic	(WX53H)
C3,4	220pF	Plate Ceramic	(WX60Q)
C5	1nF	Plate Ceramic	(WX68Y)
X1	2MHz	Crystal	(FY80B)
IR1	BC549		(QQ15R)



Note: The output from the signal generator/crystal calibrator should be connected to the receiver aerial input using coax cable (XR19V) to prevent unwanted radiation of the test signal.

Figure 11. Low cost crystal controlled calibrator.

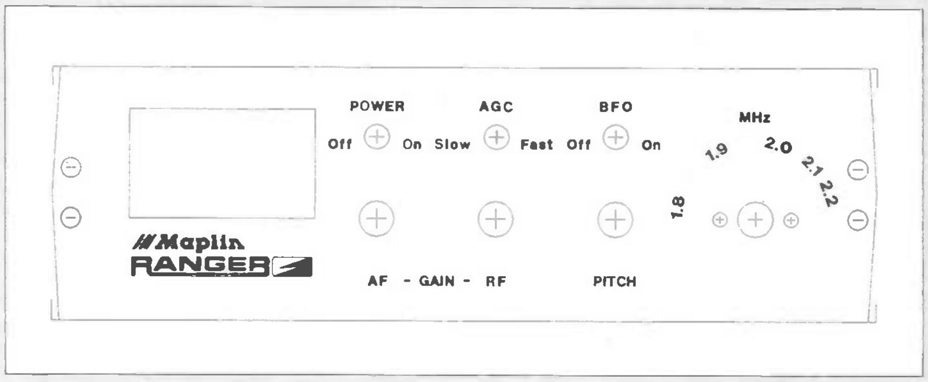


Figure 12a. Front panel layout.

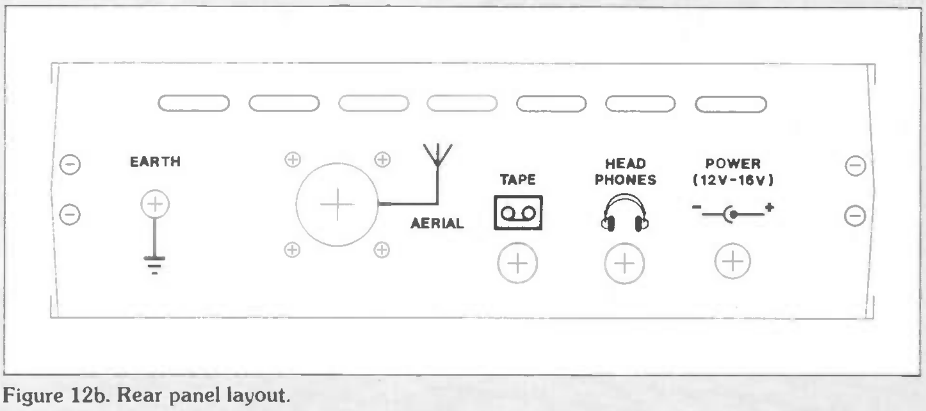


Figure 12b. Rear panel layout.

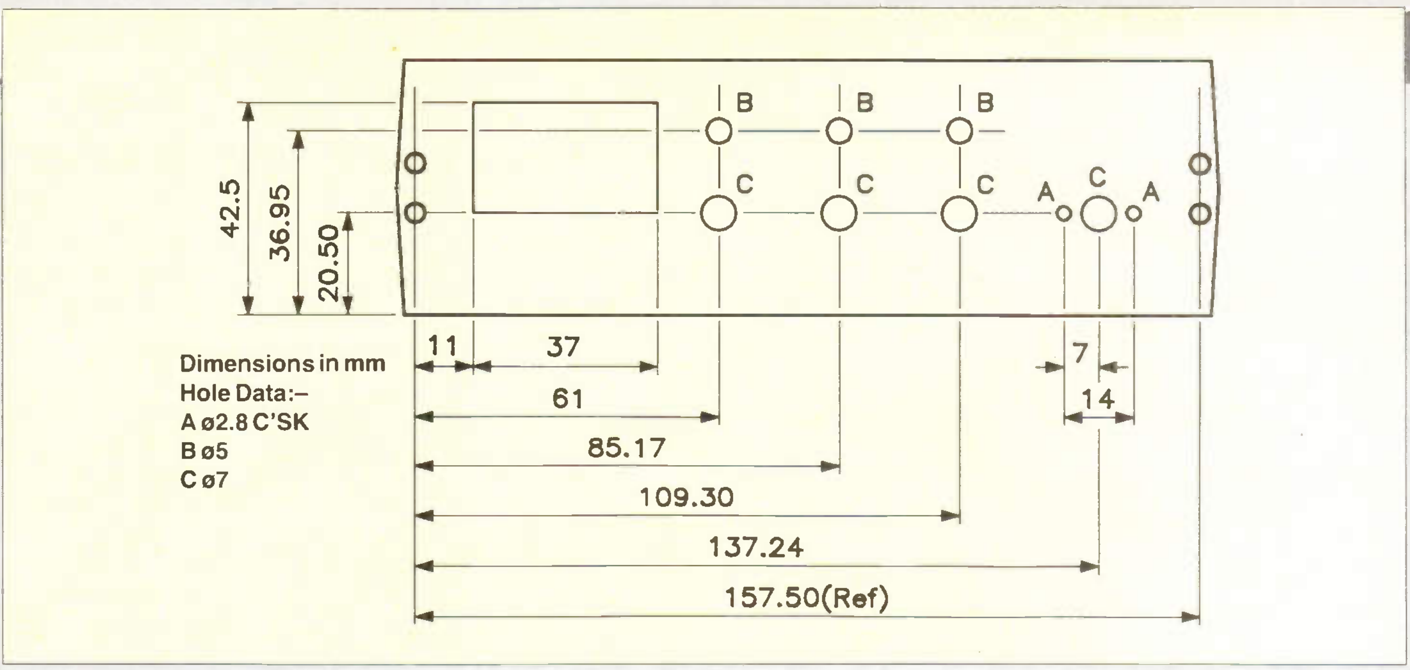


Figure 12c. Front panel drilling details.

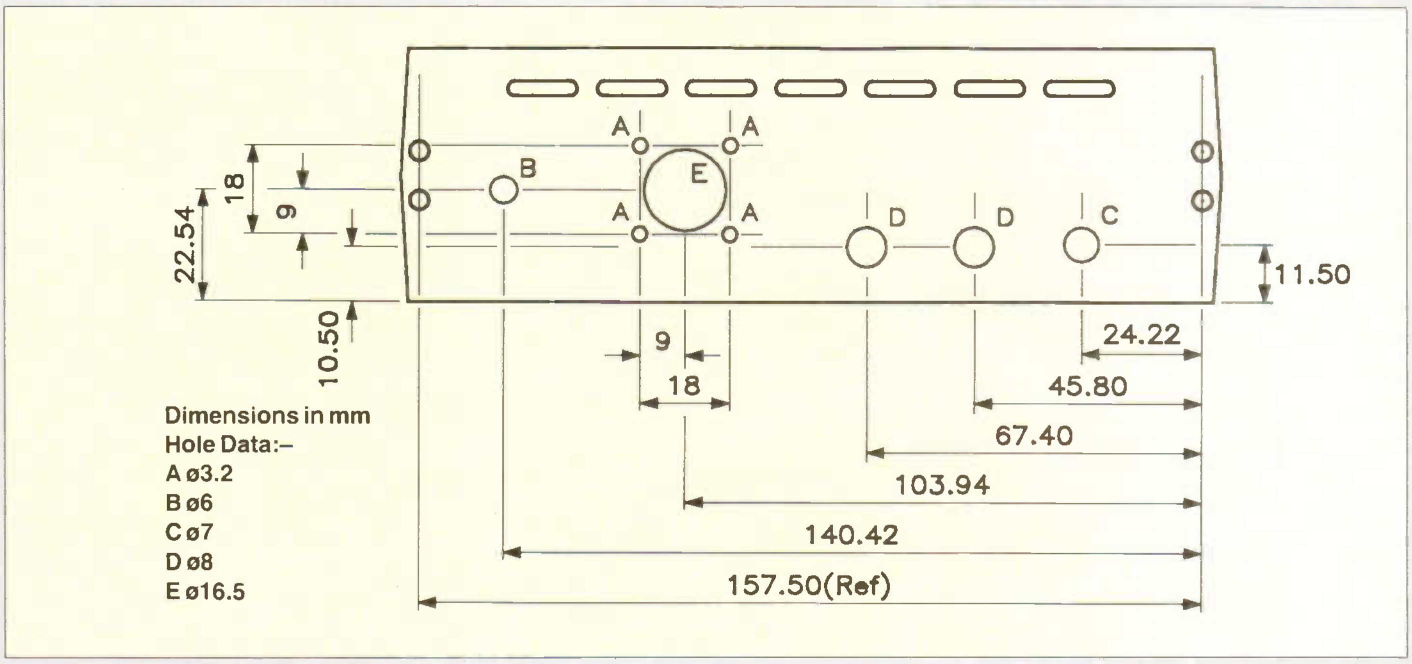


Figure 12d. Rear panel drilling details.

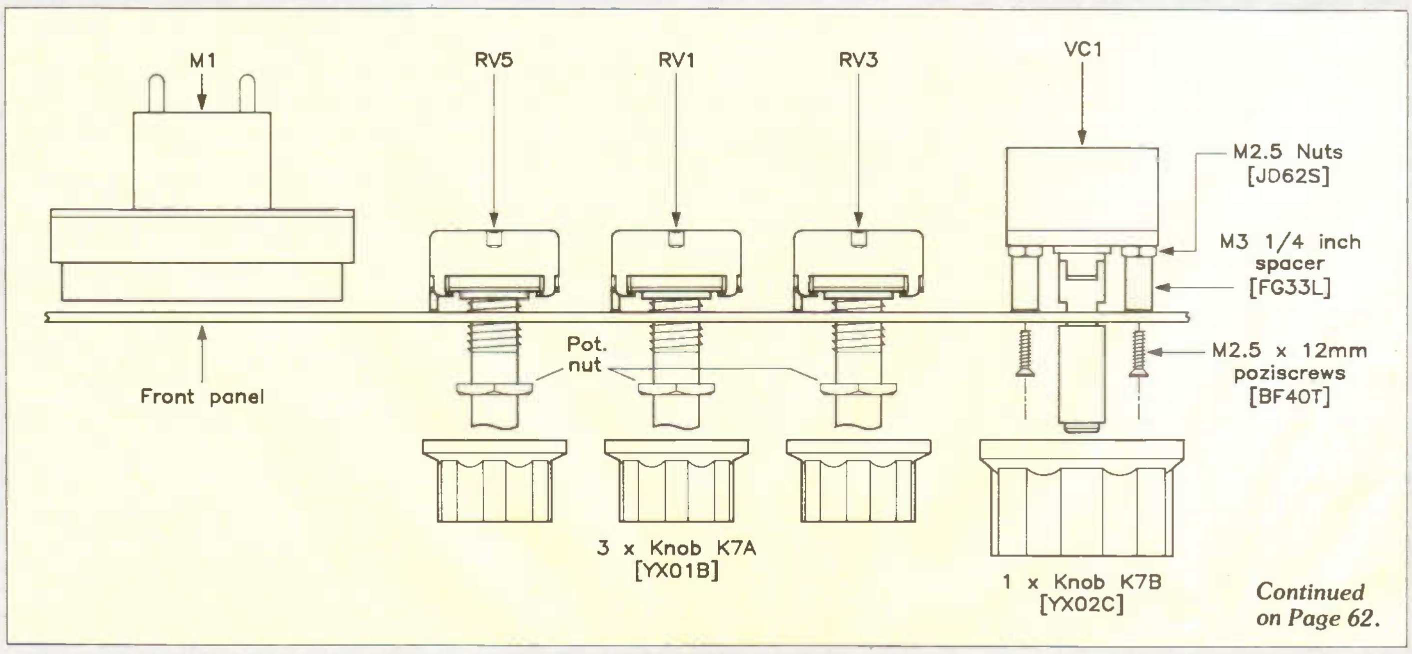


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Figure 13. Mounting the front panel components.

160m Receiver Continued from Page 55.

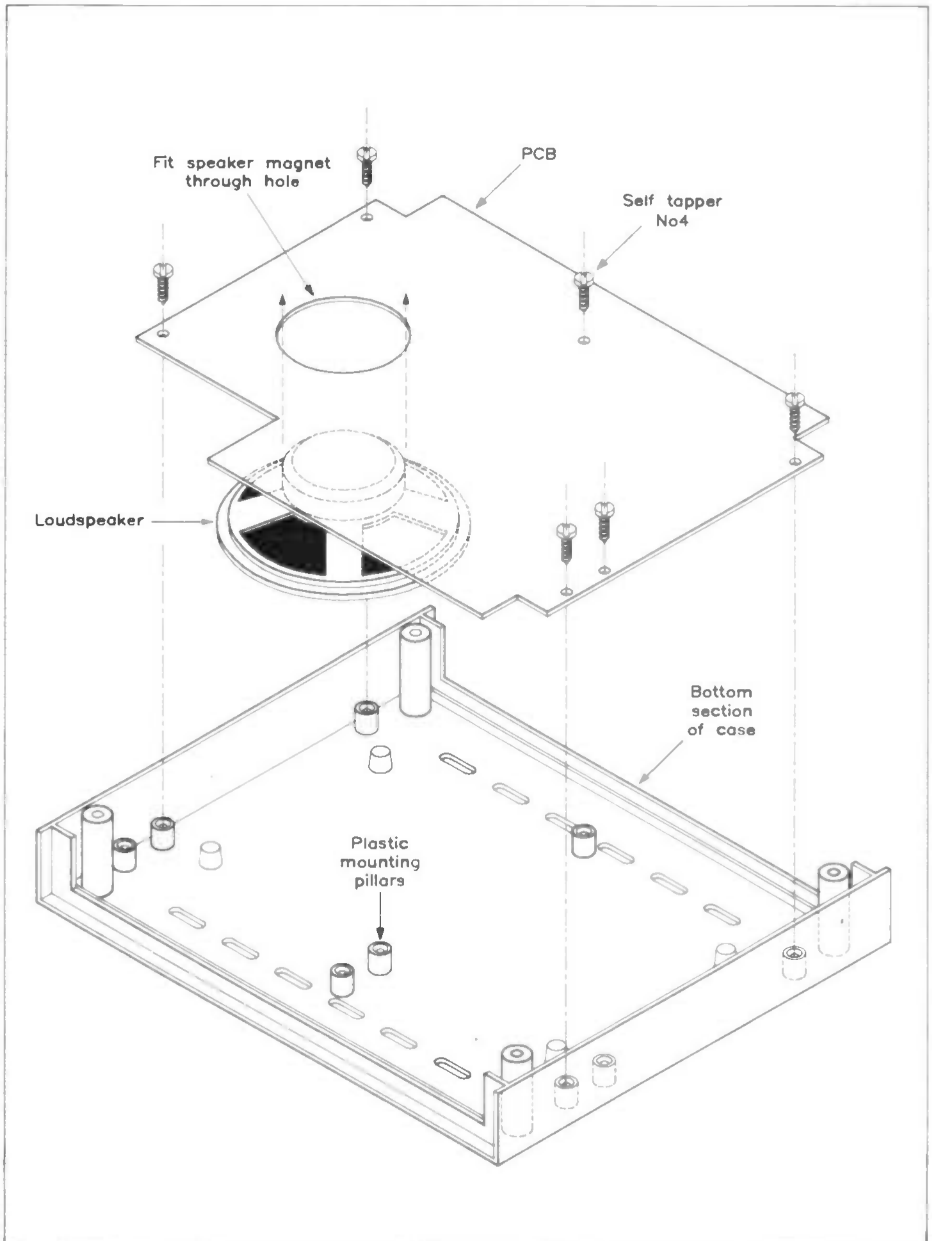

Figure 14. Mounting the PCB.

Because of the general propogation conditions at 160m, the band is usually most active during periods of darkness. During daylight hours, propogation limits effective communication range to a few tens of miles and for this reason, the number of stations to be heard in the day is that much lower than at night. During darkness hours however, ranges up to several thousand miles are often possible.

Although the majority of stations received will be using SSB, CW or data modes, AM is still very popular with amateur radio operators in some areas and it is for this reason that the AM mode is incorporated in the receiver design. Because of the type of design and the nature of the mode, the receiver is not as sensitive in the AM mode; nevertheless, reasonable performance should be obtained on the stronger signals.

Whether the AGC is set to fast or slow depends on the prevailing band conditions. There are no hard and fast rules regarding AGC settings and the choice of setting is really down to the user.

Finally Table 1 shows the specification of the prototype 160M receiver.

Power Supply Voltage	12V – 16V
Power Supply current (quiescent)	33mA
Frequency Range	1·795MHz – 2·24MHz
Sensitivity AM	less than 2·0μV
CW/SSB	less than 0·5μV
Headphone Output	4Ω – 32Ω
Intermediate Frequency	455kHz nominal
Local Oscillator Frequency	1·34MHz – 1·785MHz

Table 1. Specification of prototype.

Photo 3. Front view of the prototype unit.

Bibliography

The following books from the Maplin catalogue provide a wealth of information on antennas and receiving techniques:

Introduction to Antenna Theory (WP78K). This book explains the basic theory behind antennas, enabling the experimenter to design antennas for a variety of applications.

HF Antennas for All Locations (WS16S). A book covering a wide range of antenna ideas suitable for use in the HF band.

Shortwave Listening Handbook (WS61R). This book covers both the theory and the more practical aspects of short wave reception as well as detailing various peripherals such as aerial tuners and noise limiters. The book also explains what can be heard at different frequencies and the different types of propogation.

Additional books covering radio and related subjects may be found in the books section of the Maplin catalogue.

160 METRE RECEIVER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1.5.27.32	100R	4	(M100R)
R2	39k	1	(M39K)
R3	330R	1	(M330R)
R4.6.10.12.24	100k	5	(M100K)
R7	47k	1	(M47K)
R8.37.38	220R	3	(M220R)
R9.11.14.19.26	10k	5	(M10K)
R13.29	2k2	2	(M2K2)
R15.33.34.36	1k	4	(M1K)
R16	1M	1	(M1M)
R17	220k	1	(M220K)
R18	27k	1	(M27K)
R20	470R	1	(M470R)
R21	470k	1	(M470K)
R22.31	2k7	2	(M2K7)
R23	82k	1	(M82K)
R25	8k2	1	(M8K2)
R28	1k2	1	(M1K2)
R30	560R	1	(M560R)
R35	820R	1	(M820R)
RV1.3	47k Min Pot Lin	2	(JM73Q)
RV2.6	10k Hor Encl Preset	2	(UH03D)
RV4	4k7 Hor Encl Preset	1	(UH02C)
RV5	10k Min Pot Log	1	(JM77J)

CAPACITORS

C1	470µF 16V PC Elect	1	(FF15R)
C2.3.5.7.9.15.17. 23-26.28.29.32	100nF Minidisc	14	(YR75S)
C4.6	220pF Ceramic	2	(WX60Q)
C8	10µF 16V Minelect	1	(YY34M)
C10	68pF Ceramic	1	(WX54J)
C11.20.22.34-36	10nF Ceramic	6	(WX77J)
C12	56pF Ceramic	1	(WX53H)
C13.31	220µF 16V PC Elect	2	(FF13P)
C14	47nF Monores	1	(RA47B)
C16	3n9F 1% Polystyrene	1	(BX63T)
C18	100pF 1% Polystyrene	1	(BX46A)
C19	220pF 1% Polystyrene	1	(BX49D)
C21	4n7F Ceramic	1	(WX76H)
C27	68nF Polylayer	1	(WW39N)
C30	2n2F Ceramic	1	(WX72P)
C33	1nF Ceramic	1	(WX68Y)
VC1	Min AM Tuner	1	(FT78K)

SEMICONDUCTORS

IC1	LM3820	1	(WQ37S)
IC2	CA3140	1	(QH29G)
IC3	TDA7052	1	(UK79L)
IC4	MC1496	1	(QH47B)
TR1	3SK88	1	(UH63T)
TR2	BF244A	1	(QF16S)
TR3	MPSA14	1	(QH60Q)

MISCELLANEOUS

RG1	µA78509UC	1	(UJ55K)
RG2	µA78L05AWC	1	(QL26D)
D1.3	1N4002	2	(QL74R)
D2	1N4148	1	(QL80B)
D4	OA90	1	(QH71N)
S1.2	SPST Ultra Min Toggle	2	(FH97F)
S3	DPDT Ultra Min Toggle	1	(FH99H)
SK1	DC Power Skt PCB 2·5mm	1	(FK06G)
SK2	PCB 3·5mm Sto Skt	1	(JM23A)
SK3	PCB 3·5mm Sto DPCO Skt	1	(JM21X)
T1.2.7	KANK3333R	3	(FD02C)
T3	YRCS11098	1	(HX42V)
T4	YRCS12374	1	(YG30H)
T5	YHCS11100	1	(HX43W)
T6	YMCS17104	1	(YG32K)
M1	Signal Strength Meter	1	(LB80B)
L1	Choke 100µH	1	(WH41U)
	8 Pin DIL Socket	2	(BL17T)
	14 Pin DIL Socket	2	(BL18U)
	Pins 2145	1Pkt	(FL24B)
	Loudspeaker Lo-Z668	1	(WB13P)
	Isobolt M2·5 20mm	1Pkt	(JD15R)
	M4 × 0·5in Spacer	1Pkt	(FG37S)
	Hook-Up Wire (7/0·2mm)	1Pkt	(BL00A)
	PC Board	1	(GE49D)
	Constructors' Guide	1	(XH79L)
	160m Receiver Leaflet	1	(XK28F)

OPTIONAL (not in kit)

SK4	SO239 Skt (Square)	1	(BW85G)
	Grounding Post with 4mm Skt	1	(JL99H)
	Isobolt M3 × 6mm	1Pkt	(BF51F)
	Steel Nut M3	1Pkt	(JD61R)
	Isoshake M3	1Pkt	(BF44X)
	Isotag M3	1Pkt	(LR64U)
	Case 3502	1	(YN33L)
	Poziscrew M2·5 12mm	1Pkt	(BF40T)
	M3 ¼in Spacer	1Pkt	(FG33L)
	M2·5 Nuts	1Pkt	(JD62S)
	Self Tapper No.4	1Pkt	(FE68Y)
	Front Panel	1	(JX41U)
	Back Panel	1	(JX42V)
	Knob K7A	3	(YX01B)
	Knob K7B	1	(YX02C)

The above items, excluding Optional, are available as a kit:
Order As LP31J (160m Receiver) Price £36.95

The following items are also available separately but are not shown in our 1991 catalogue:

160m Receiver PCB Order As GE49D Price £11.95
Front Panel Order As JX41U Price £3.25
Back Panel Order As JX42V Price £3.25