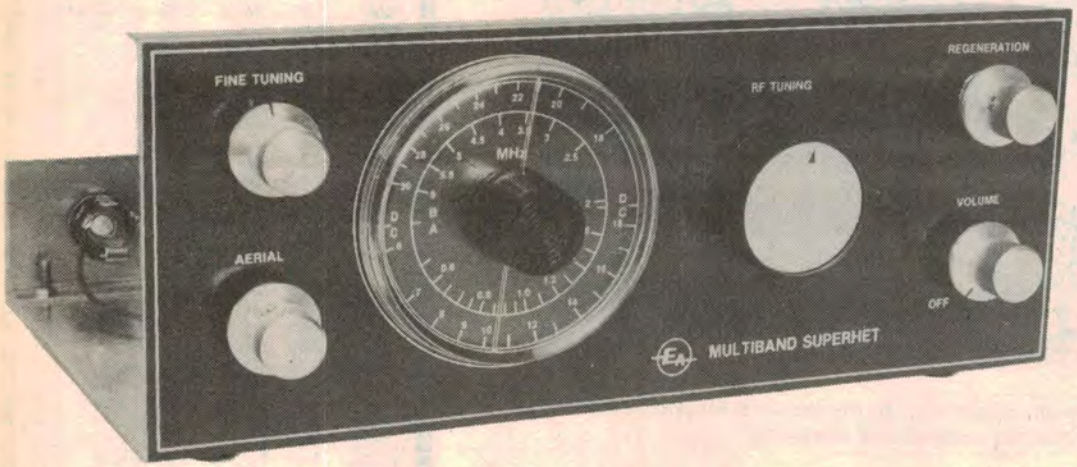
Build a superhet shortwave receiver



Our new superhet shortwave receiver is built on a simple folded aluminium chassis and finished with a "Scotchcal" front panel. The unit covers the broadcast band and from 2-30MHz.

This "Multiband Superhet" receiver is a step or so beyond the All-Wave Three described last April. It offers high performance with surprisingly good sensitivity and selectivity and covers the broadcast band and from 2MHz to 30MHz. If you liked the All-Wave Three, you will like the "Multiband Superhet" even better.

by IAN POGSON

The "All-Wave Three" receiver which we described in May, 1980 was a very popular and successful project, having been built up in large numbers. This made us think about the possibility of describing a unit with more performance but still retaining the basic simplicity of the All-Wave Three. With this idea in mind, we came across an interesting simple design for a superhet in "Radio and Electronics Constructor", for February, 1980. Using this design as our basis, we have added some refinements to come up with the unit to be described.

While we would hesitate to claim that this new receiver would match more expensive commercial receivers, given a good antenna and some skill in operation, you may virtually have the world at your doorstep! One thing is certain, for the modest outlay in money, the return in satisfactory performance should be well worth while.

To get an idea as to how this has been made possible, let us have a look at the circuit. The first stage employs a dual-gate field-effect transistor as a mixer. The incoming signal from the antenna is fed via a 5k potentiometer working as an antenna attenuator and then to the tuned circuit consisting of a plug-in coil and a standard variable capacitor. The signal then passes on to gate one of the BFR84 FET. Bias for the FET is obtained with a 390 ohm resistor in the source circuit. Injection from the local oscillator is via a .001uF capacitor into gate two of the FET.

Because of the mixer action of the FET, the incoming signal is converted to an intermediate frequency (IF) of 1.8MHz. This is fed from the drain of the FET to the primary winding of a 1.8MHz IF transformer. The secondary of this transformer feeds the gate of a 2N5485 junction FET, operating as a source-follower. A potentiometer in the source circuit of the FET provides positive feedback to the secondary of the IF transformer. Although the gain of the source follower is less than unity, oscillation is possible by virtue of the step-up available from the tapped secondary of the IF transformer.

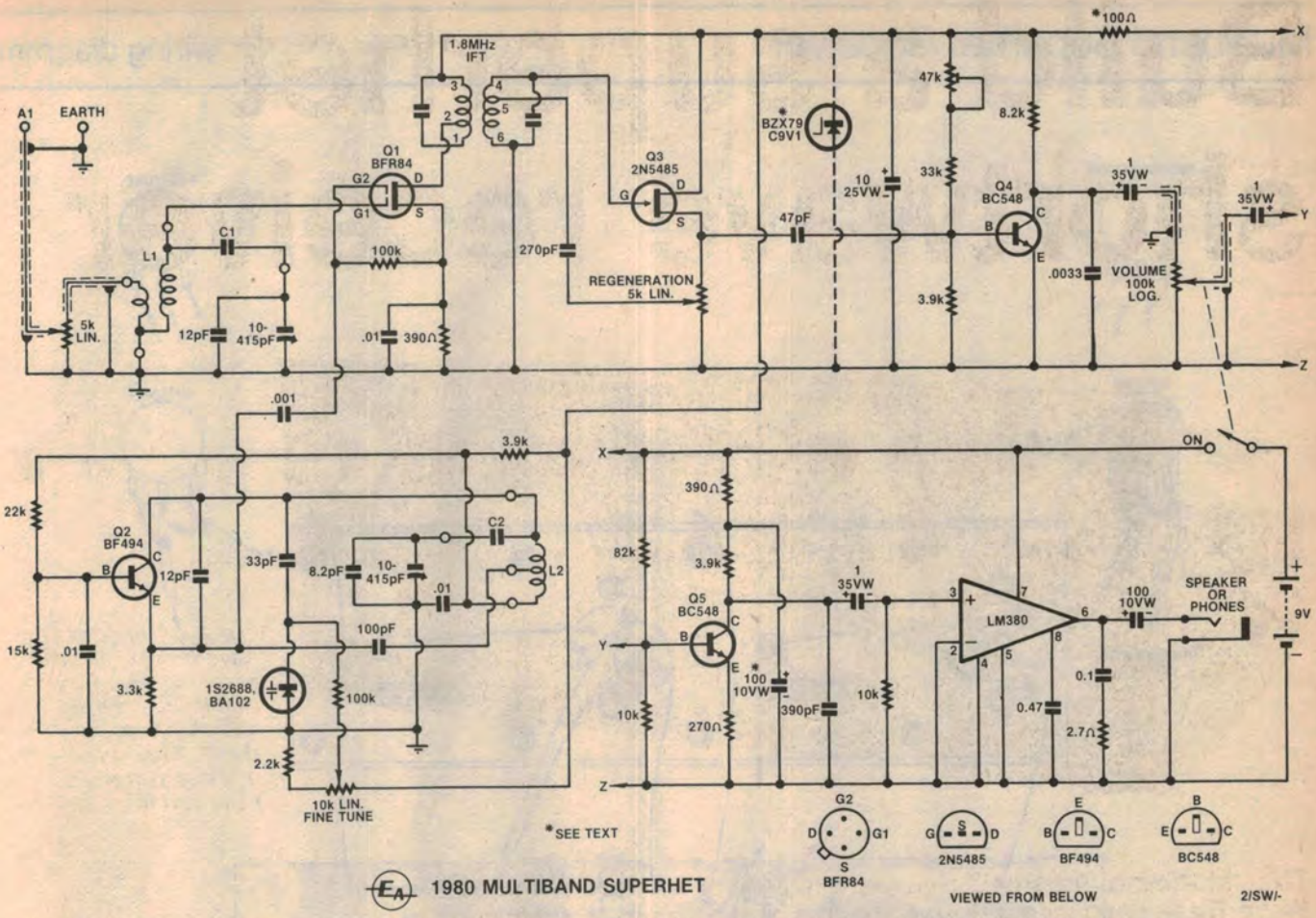
Very smooth and stable regeneration is available with this arrangement, resulting in markedly increased gain and selectivity, compared with what would be obtained without it. Also, when the stage is made to oscillate, reception of CW and SSB signals is possible.

Output from the source of the 2N5485 is coupled into the following stage, a BC548 operating as a class-B detector. Unlike diode detectors, the class-B detector gives a substantial amount of gain. The 47k trimpot in the base circuit of the detector allows optimum operating conditions to be set.

Audio from the detector is passed through the 100k volume control to the audio amplifier which is the popular LM380. Because the fixed gain of 50 of the LM380 is insufficient in this application, we added a transistor preamplifier. The LM380 is capable of driving a speaker of eight or 16 ohms.

As well as providing for loudspeaker use, it is also possible to use a set of low impedance headphones. When listening to those really distant weak stations, headphones can make all the difference in being able to pick them out from the noise.

The local oscillator uses a BF494 bipolar transistor which is intended for high frequency applications. This oscillator circuit has been used many times in the past and it has proved to be very stable. In order to keep costs down, we have used a simple handspan dial to drive the tuning capacitor directly. This is all right for tuning the stronger broadcast



The circuit provides good performance for relatively modest outlay and can resolve AM, CW and SSB signals.

stations but when it comes to tuning the weaker shortwave stations, the extra "band-spread" afforded by the fine tuning knob makes tuning very much easier. The varicap diode is connected across the main tuning circuit and a 10k potentiometer controls its capacitance.

We have provided for battery operation but this little receiver can be run from the mains, using any plug-pack power supply which will deliver more than nine volts but no more than about 12V DC, at up to about 100mA. For this situation, provision has been made on the board for a 9V zener diode to be fitted. The 100 ohm series resistor may need to be increased if the supply voltage exceeds about 12V. This arrangement supplies the RF stages with regulated 9V, while the rest of the receiver is fed directly from the plug-pack. For battery operation omit the zener diode.

COMPONENT AVAILABILITY

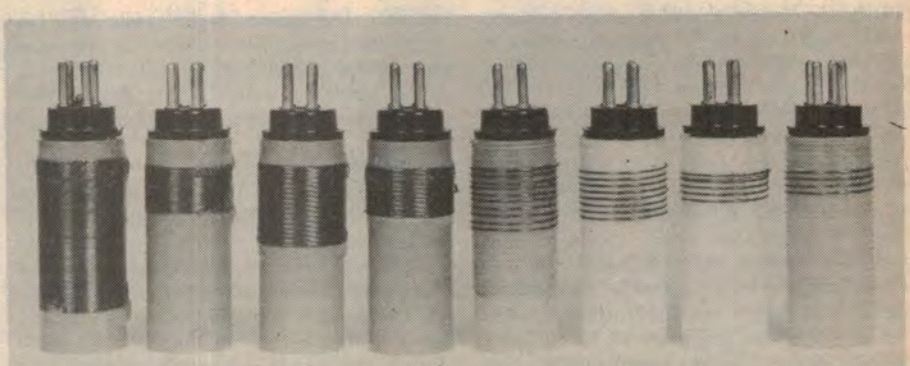
At the time of writing, all the components used on the Multiband Superhet are available but comments on some of the items may be helpful.

In order to reduce the cost of building this project, many readers may be able to salvage some components from old radio and possibly television receivers. While we used new components in the prototype, there is no reason why you should not save a few dollars here and there.

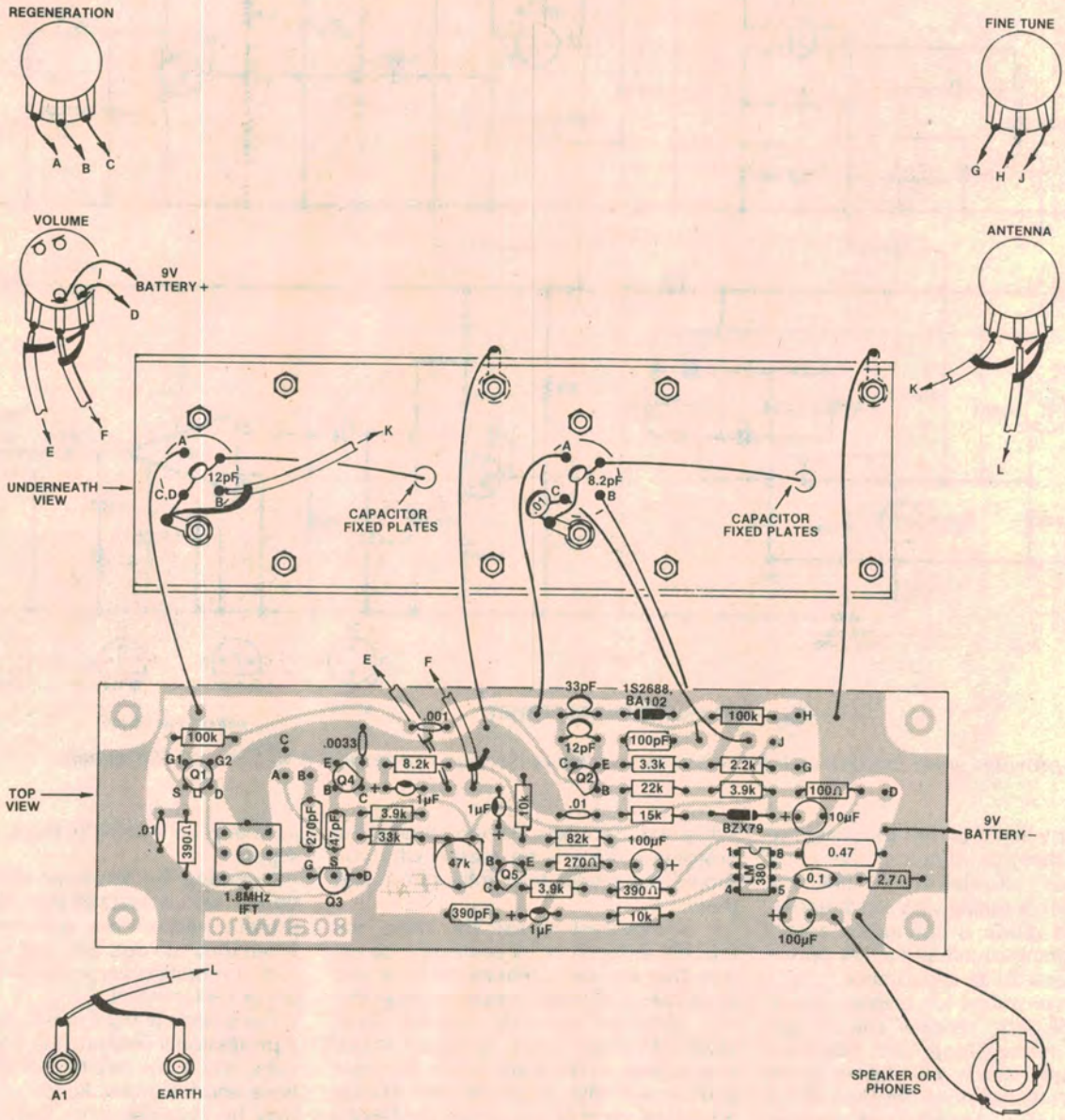
It is important to use the same coil formers as used on the prototype, to ensure that the dial calibrations track and to obtain similar performance generally. We obtained our coil formers from Watkin Wynne Pty Ltd, 32 Falcon Street, Crows Nest, NSW 2065. From the same source, we also obtained the Roblan 10–415pF variable capacitors, the Denco IF transformer type IFT18–1.6MHz and the handspan dial. These items should normally be available from your local supplier.

Regarding the handspan dial just mentioned, we understand that stocks of the present version are running low and when they run out, they will be replaced with a modified version which will be a direct replacement.

The Scotchcal front panel overlay gives a professional finish to the unit and provides the extra facilities of dial calibrations and functions. Ready made panels may be obtained from Radio Despatch Service, 869 George Street, Sydney, or Rod Irving Electronics, 499 High Street,



Eight plug-in coils are used to cover the frequency range from 0.5 to 30MHz. Full winding details for the coils are given in the text.



This wiring diagram shows the sub-chassis as viewed from below, while the PC board is shown from the component side.

Northcote, Victoria, and possibly others.

We used a metal "L" shaped chassis to accommodate the components, together with the sub-chassis and PCB assembly. Although it may be possible to use a wooden base, it is not recommended for this project. A metal front panel is a "must", in order to minimise hand capacitance effects when tuning. Also, if you live near to any high powered broadcast transmitters, it will also be necessary to provide an earthed metal top plate, corresponding to the top of a cabinet, to prevent these very strong signals from overloading the receiver.

It is very important to make the finished assembly quite rigid, for frequency stability. The assembled chassis may be fitted into a suitable cabinet to improve the overall appearance. Of course, a metal cabinet would also avoid the overloading problem mentioned above.

ASSEMBLY DETAILS

Although the Multiband Superhet is a modest receiver, there is quite a lot of work in assembling it. However, by using a PCB the job is simplified and the chance of making wiring errors is reduced. There is no particular order in which the job should be tackled but all sub-assemblies should be made up first.

A logical place to start is to wind the coils. The relevant information is given in the coil table and must be followed closely. To ensure that the coils perform similarly to those of the prototype, it is important to use the gauges of wire called for in the table, otherwise there will be deviations from the original windings and it is possible that the calibrations on the dial will be inaccurate.

McMurdo 4-pin plugs are fitted to the coil formers by means of a screw. We tapped the centre hole to ⅛in Whitworth and dropped a screw down through the former. This makes a very neat assembly. However, if you are unable to tap the holes, then it may be an idea to open up the hole if necessary and use a countersunk screw up through the plug and into the former and screwing on a nut. Whatever method is used, the plug

must be solidly fixed to the former.

In most cases, a small hole will be drilled in the appropriate place on the coil former through which the wire will pass, on its way to the terminating pin on the plug. Where this is not possible, as at the top end of some of the antenna primary windings, the winding may be fixed with a piece of adhesive tape. In fact, it is wise to use some spots of clear adhesive, like Tarzan's Grip, to hold the windings firmly in place.

Do not forget to fit the padder capacitors C1 or C2, or a link where called for. These items are fitted directly to the 4-pin plug and inside the base of the coil former.

Because of the requirement for plug-in coils and two separate tuning gangs, we mounted these components on a separate sub-chassis which provides a high degree of rigidity as well as simplifying the details of assembly. The sub-chassis can be made of steel or aluminium, using the dimensions shown in the diagram.

The sub-chassis must be assembled and wired before it is installed on the chassis.

When assembling the PCB it is usually best to start with the small components, such as resistors and diodes, followed by capacitors and then the larger components. It is important to observe the correct polarity of components, such as electrolytic and tantalum capacitors, the diode, the IC and transistors.

A good soldering iron should be used and care should be taken to make good soldered joints, without overheating any components. Resin cored solder only should be used and on no account should any corrosive fluxes be used. The latter can destroy an otherwise good job.

The "L" shaped chassis may be bent up from a piece of aluminium, or other sheet metal, such as a piece of galvanised iron, etc. The dimensions given in the parts list are inside measurements and a stiffening lip about 8mm wide is included at the top of the front panel and at the back edge. Care must be taken to get dimensions correct, so that the variable capacitor spindles pass through the exact centre of the holes on the front panel.

Fixing the Scotchcal overlay to the front panel requires a considerable amount of care, as once it has been applied to the panel, it is almost impossible to remove. Make sure that it is square with the panel and in the right position before pressing it in place.

The sub-chassis with the two variable capacitors and the plug-in coils, is stood off the main chassis with four 19mm-long tapped spacers. The front edge of the sub-chassis should be set up against the inside face of the front panel. The PCB is mounted on the main chassis so that its front edge is about 2mm behind the back edge of the sub-chassis. We mounted the PCB with four screws and by means of two extra nuts for each screw, stood the PCB off the chassis by about 5mm. Before mounting the PCB, a hole should be drilled in the bottom of the chassis so that an aligning tool may be passed through to adjust the slug in the IF transformer.

We mounted the jack for the loudspeaker and headphones on a small bracket on the rear of the chassis and near one end. Similarly, the antenna and earth terminals were mounted on another bracket, near the other end of the rear of the chassis. In between, there is ample space for a 9V battery, such as a type 276.

Considerable care should be taken when terminating all the leads to and from the PCB. This applies particularly to the leads from the coil sockets on the sub-chassis. Leads should be as short as possible, particularly from the coil sockets and the volume control. Leads to the volume control and from the antenna terminal to the potentiometer and the coil socket should be run in shielded cable.

When fixing each of the knobs to the spindles, due regard should be given to the direction of the pointer. The hand-span dial knob for the main tuning

Parts List for the Multiband Receiver

1 Front panel 262 × 104mm
1 Metal chassis 262 × 104 × 165mm
2 Brackets 50 × 40 × 12mm (for terminals and jack socket)
1 Sub-chassis 153 × 44 × 8mm (see diagram)
1 Cabinet to suit (optional)
1 6.5mm mono jack socket for headphones or loudspeaker
2 Jabel spring-loaded terminals
2 5k (linear) potentiometers
1 10k (linear) potentiometer
1 100k (log) potentiometer with switch
4 Knobs for potentiometers
1 Knob for RF tuning
1 Jabel "handspan" dial knob, or similar
2 Roblan single gang variable capacitors 10-415pF
2 McMurdo 4-pin sockets
8 McMurdo 4-pin plugs
4 Jabel coil formers (plain) 20mm diameter × 51mm long
4 Jabel coil formers (grooved) 20mm diameter × 51mm long
4 Tapped brass spacers, 19mm long
4 rubber feet

1 PCB 171 × 53mm, code 80aw10
1 Denco IF (transformer type IFT18-1.6MHz (see text)
1 BFR84 N-channel dual IGFET
1 2N5485 N-channel JFET
1 BF494 transistor
2 BC548 transistors
1 LM380 audio power amplifier, 8-pin DIL
1 8-pin DIL socket
1 1S2688/BA102 varicap diode
1 BZX79 9V1 zener diode (see text)
1 276-P 9V battery or plugpack DC supply (see text)
1 47k miniature horizontal trimpot

RESISTORS (¼W or ½W)
2 × 100k, 1 × 82k, 1 × 33k, 1 × 22k, 1 × 15k, 2 × 10k, 1 × 8.2k, 3 × 3.9k, 1 × 3.3k, 1 × 2.2k, 2 × 390 ohms.

CAPACITORS
2 100uF/10VW electrolytic (see text)
1 10uF/25VW electrolytic
3 1uF/35VW tantalum
1 0.47uF metallised polyester (greencap)
1 0.1uF greencap
3 .01uF greencap
1 .0033uF greencap
1 .0012uF greencap
1 .001uF greencap
2 390pF polystyrene
1 270pF polystyrene
2 220pF polystyrene
2 180pF polystyrene
1 150pF polystyrene
1 100pF polystyrene
1 47pF polystyrene
2 33pF NPO ceramic
2 12pF NPO ceramic
1 8.2pF NPO ceramic

MISCELLANEOUS
Screws, nuts, hookup wire, solder, solder lugs, light coaxial cable, enamelled copper wire for coils.

NOTE: Ratings are those used on the prototype. Components with higher ratings may generally be used providing they are physically compatible. Components with lower ratings may also be used in some cases, provided the ratings are not exceeded.

should be set with the cursor horizontal when the capacitor moving plates are fully closed. The RF tuning knob should be set with its pointer horizontal with its capacitor moving plates fully meshed. These two knobs will then point in approximately the same direction when tuning across the various bands. The fine tuning knob will be set after the receiver has been put into operation.

At this stage, the unit is almost ready for testing. Before proceeding however, all work should be thoroughly checked. Make sure that all components are in the right place and that polarities are correct. All wiring should also be checked for accuracy. Satisfied that all is well, the battery or other supply may be connected, also with due regard to polarity.

Assuming that all is well, we are now ready to put the Multiband Superhet into operation. Plug in the coils for the broadcast band, 520kHz–1600kHz, making sure that the coils are in their correct positions. Set the two variable capacitors to about mid-position, with the antenna potentiometer fully advanced and the regeneration potentiometer fully anticlockwise. Inject 1.8MHz from a signal generator into the antenna and earth terminals. Keep the generator to the lowest level consistent with sufficient signal. Switch on and with the volume control suitably set, adjust the two slugs in the IF transformer for maximum audio level.

The fine tuning knob can best be set by making the adjustment at a high frequency. Plug in the coils covering the 18MHz–30MHz range and make the adjustment at around 28MHz. Again using the signal generator, set the fine tuning knob so that with the rotor and the pointer vertical, somewhere between the extremes of travel, rotating the control in each direction will give equal amounts of frequency tuning.

HINTS ON USING THE MULTIBAND SUPERHET

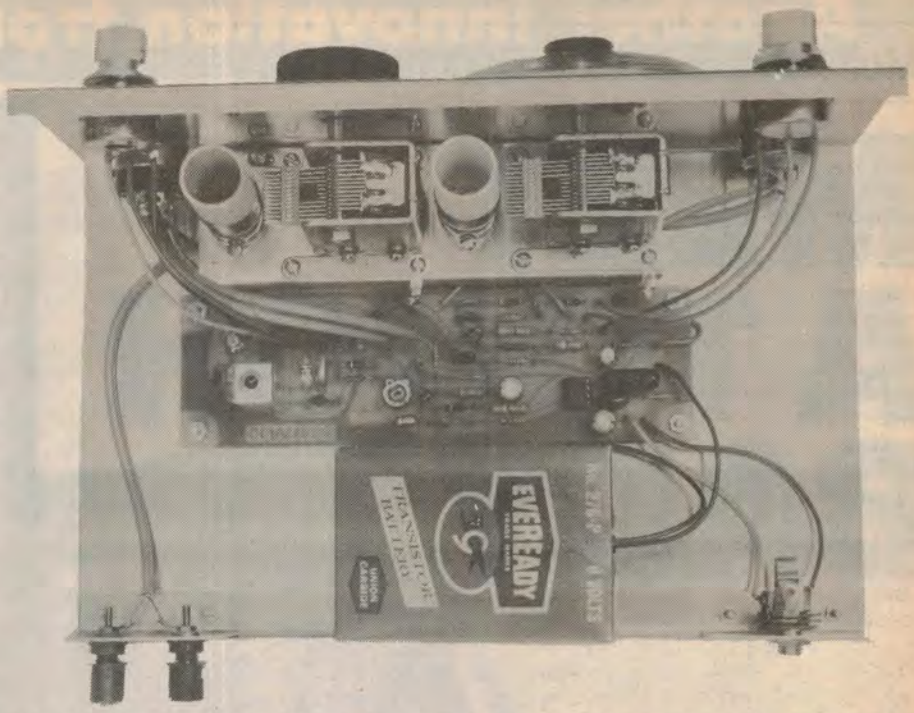
Here are some pointers which should be useful as a guide to the tuning and operation of this kind of receiver.

For the reception of morse code or "CW" signals, the IF stage is brought to the point of oscillation and then the signal is tuned slightly to one side or the other, thus producing a signal or beat note. The note is selected to suit the convenience of the listener. The side selected does not matter but if interference is present it can often be avoided by selecting a particular side.

When the reaction or regeneration in the IF stage is increased, the sensitivity is also increased and selectivity is sharpened as well. Sensitivity and selectivity reach a maximum just at the point of oscillation. For the reception of AM signals, the regeneration should normally be set just below the point of oscillation. However, when attempting to receive very weak signals which are not satisfactory under these conditions, it is often possible to copy them if the IF stage is made to oscillate and the signal carefully tuned so that there is no whistle.

For SSB reception, the IF stage is also made to oscillate and the signal is resolved by carefully tuning for the best speech quality. It is important to note that when the IF stage is made to oscillate for all the conditions just mentioned, there is no point in advancing the regeneration control beyond the position where reliable oscillation is achieved.

Another point concerns adjustments for volume with strong AM signals. It is better not to back off the regeneration



This photograph clearly shows the general layout of the receiver. The sub-chassis (top) is mounted on the main chassis using four 19mm brass spacers.

Coil winding details

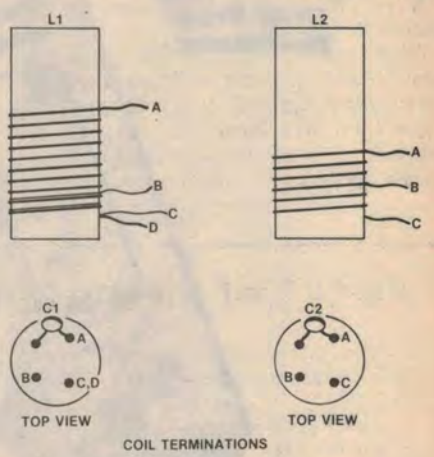
Range 1: 520kHz-1600kHz
L1 Secondary, 155 turns 32B&S enamel close wound. Primary, 15 turns 32B&S enamel close wound over cold end of secondary. C1, link.
L2 46 turns centre tapped 32B&S enamel close wound. C2, 110pF (two 220pF in series).

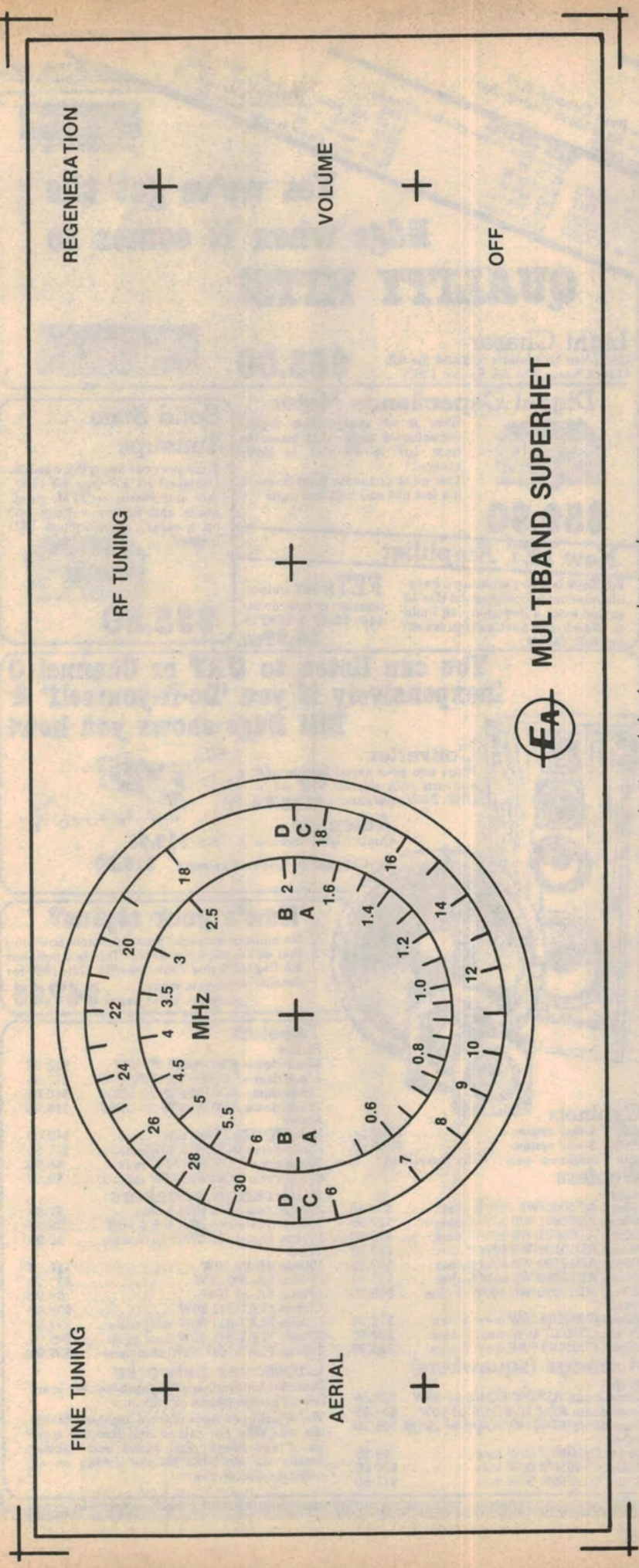
Range 2: 2MHz-6MHz
L1 Secondary, 34 turns 24B&S enamel close wound. Primary, 4 turns 32B&S enamel interwound at cold end of secondary. C1, link.
L2 20 turns centre tapped 24B&S enamel close wound. C2, 423pF (390uF and 33pF in parallel).

Range 3: 6MHz-18MHz
L1 Secondary, 10 turns 24B&S enamel wound 6 turns per cm. Primary, 2 turns 32B&S enamel interwound at cold end of secondary. C1, link.
L2 8 turns centre tapped 24B&S enamel wound 6 turns per cm. C2, 1380pF (1200pF and 180pF in parallel).

Range 4: 18MHz-30MHz
L1 Secondary, 4½ turns 24B&S enamel wound 6 turns per cm. Primary, 1 turn 32B&S enamel interwound at cold end of secondary. C1, 180pF.
L2 4 turns centre tapped 24B&S enamel wound 6 turns per cm C2, 150pF.

All coils wound on Jabel plastic formers, 20mm diameter × 50mm long and mounted on McMurdo 4-pin plugs. Smooth formers used for close wound coils and pre-grooved formers used for coils wound 6 turns per cm (16 turns per inch).





Here is an actual size reproduction of the front panel artwork.

control if the volume is too high. This practice will reduce the volume but the selectivity will be degraded as well. Whether this method is used to some extent will depend upon prevailing conditions.

With this particular receiver, in addition to the above, it is possible for very strong signals to overload the detector. This comes about because there is no automatic gain control, which normally would prevent this from occurring. To cope with this situation, we have provided an attenuator in the form of a potentiometer in the antenna circuit. The attenuator is adjusted to stop overloading where this is experienced. This situation is most likely to occur on strong local broadcast stations but it can also happen with some very strong overseas shortwave stations.

As mentioned earlier, we have used a direct drive dial for the main tuning and this has been supplemented with a "fine tuning" control. In practice, particularly on the higher frequencies, the main tuning control should be set about the middle of an immediate tuning range of interest. This setting is then maintained and tuning for each individual signal is carried out by the fine tuning control. When the range of the fine tuning control is insufficient to proceed further, then the main tuning control should be readjusted.

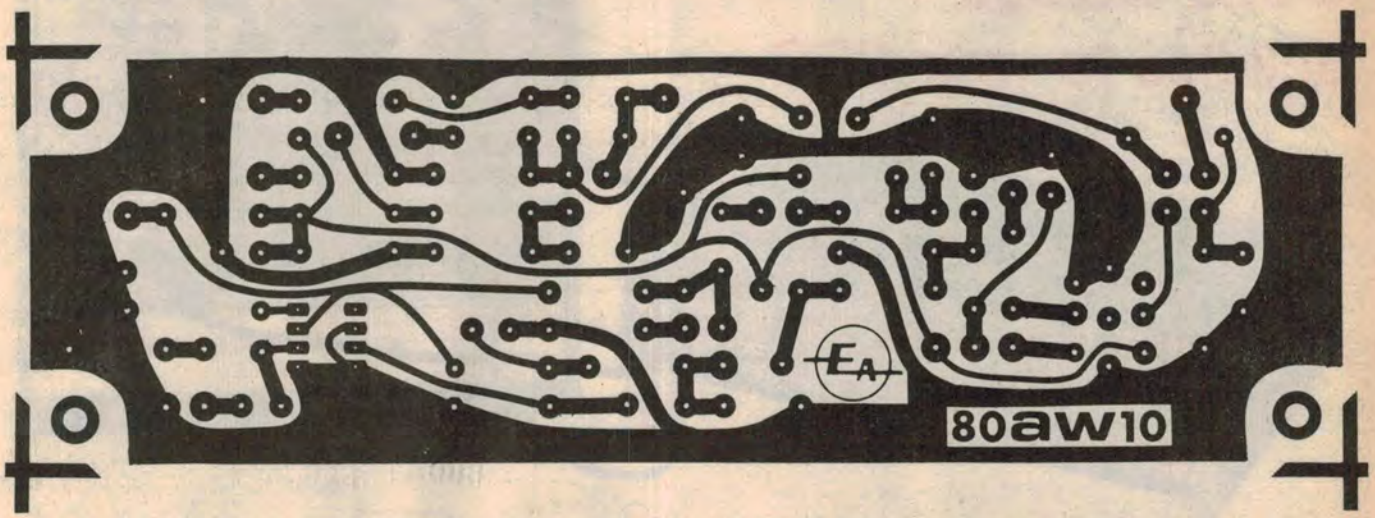
We estimate that the current cost of parts for this project is approximately

$65.00

This includes sales tax.

Suitable antennas for the Multiband Superhet could be quite a topic in itself. For best results over the full coverage of the receiver, a number of different types of antenna would be desirable. The needs will vary according to the location and the frequencies on which most interest rests. In addition, a good earth connection is required. A fairly heavy gauge of wire should be run to the nearest water pipe and clamped to it.

As a guide, for the broadcast band and frequencies up to about 3MHz, a random length of wire would be suitable. This may be inside or outside and of such a length as suits local conditions, proximity of wanted stations, etc. For general shortwave reception, the "Twin Doublet Aerial" as described in the issue



Above is an actual size reproduction of the PC artwork, while below is a metalwork diagram for the sub-chassis.

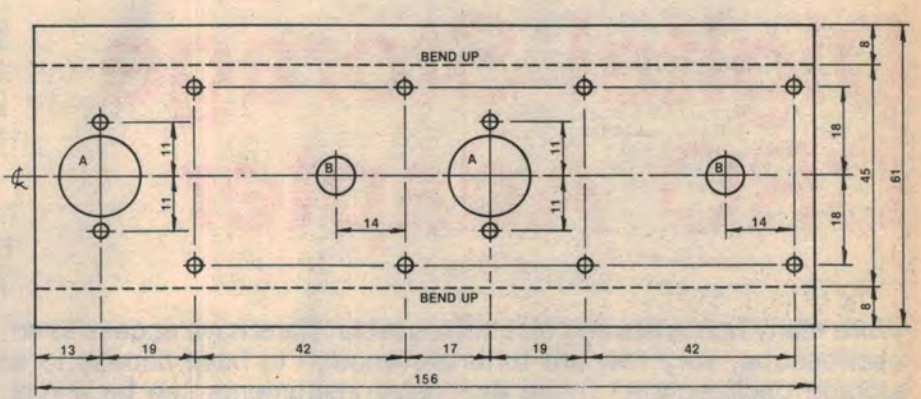
for November, 1963 would be very suitable. If, on the other hand, the amateur bands are of prime importance, then an antenna designed especially for these bands would be the logical choice.

We tested the prototype in our City laboratory under very adverse conditions. However, in spite of this, it gave a very good account of itself. Of course, all of the local broadcast stations were there. In fact, for most of them, we turned the antenna attenuator almost right down. Other out of town broadcast stations were also logged – the antenna attenuator was brought up as necessary. It is also worth noting that two of these more distant stations were only 9kHz apart and they could be reasonably well separated.

By plugging in each of the sets of shortwave coils, we were able to tune in stations on various bands, particularly on the 31 and 25 metre bands. Deutsche Welle, Madrid, London, Voice of America, etc, were all there, together with signals on the Citizen's Band, time signals and more. Unfortunately, due to our location, some of the signals were badly affected by electrical noise. The alternative was to take the receiver home and try it out under more typical conditions.

At home, I connected a multi-band antenna designed for amateur frequencies and tuned the three shortwave ranges provided by the appropriate coils. From early evening and for the next two hours or so, I tuned in literally hundreds of overseas and local shortwave signals. Most of the signals were on AM but some signals in the amateur bands on CW and SSB were also tuned.

Plugging in the broadcast band coils, I was able to tune in all of the local stations and many distant and interstate stations. However, the overloading problem was evident on the local stations, even without any antenna at all but by introducing a top shielding panel, this problem was overcome.



A : 16 DIA B : 8 DIA UNMARKED HOLES 3.2 DIA DIMENSIONS IN MILLIMETRES

After handling the "Multiband Superhet" under typical conditions, may I offer some suggestions which could help in getting the best out of the receiver. All of the control knobs are important and experimentation and observation as to the use of each one will pay good dividends. Experiment with antennas, from large outdoor ones to short pieces of wire indoors. Different antennas may give better results than others, for different frequency bands. A small variable trimmer capacitor, up to about 100pF may be tried in series with the antenna right at the antenna terminal.

While the LM380 audio amplifier, with a 9V supply will drive a loudspeaker, it is not capable of giving much volume. A better way is to use a pair of headphones and so get more satisfactory volume and better copy of weak signals.

Finally, I would recommend that the receiver be fitted into a metal cabinet, preferably with a hinged lid to facilitate coil changing. The metal cabinet will reduce to a minimum the overload problem from local high powered transmissions. I wish you good listening.