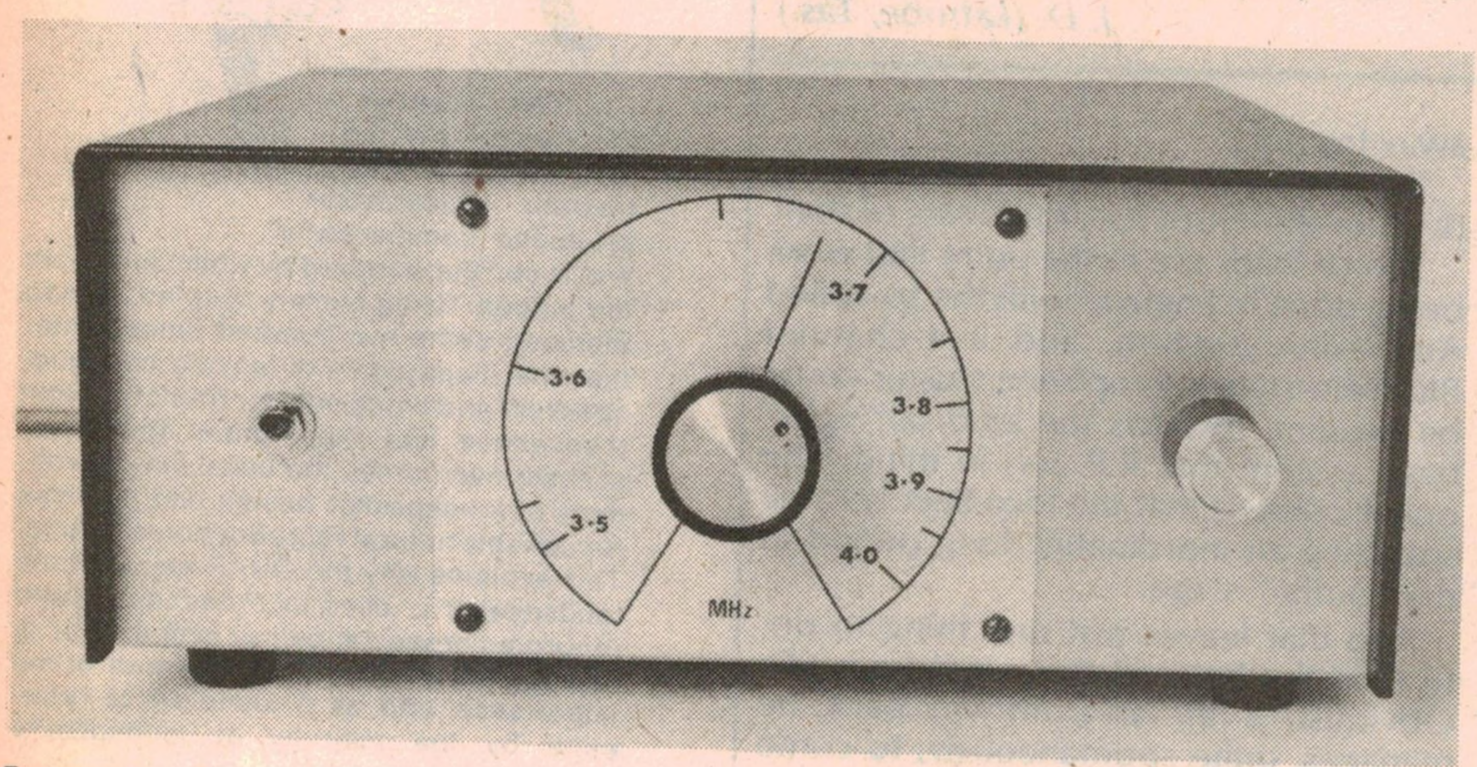
A direct conversion receiver for 3.5MHz

Following on from our recent articles describing transmitting gear mainly intended for the new amateur Novices, we now present a simple receiver for the 3.5MHz band. It uses the "direct conversion" principle, and is in fact the first such receiver we have described. It offers good reception of CW and SSB signals using simple circuitry.

by IAN POGSON

Direct conversion receivers have been described in overseas magazines for the past ten years or so, and possibly longer, but we have not entered the field until now. Like most things, there are arguments both for and against.

One of the very favourable points about direct conversion is its relative simplicity. On the other hand, while they are quite good for CW and SSB reception, they are not the best for AM reception. Also, as all or nearly all of the gain is at audio frequencies, problems of hum and instability have to be overcome.



Front panel controls are (left to right) mains on/off, tuning and volume.

However these problems are not insurmountable and direct conversion receivers can give quite a good account of themselves despite the performance limitations.

Before we go any further, I imagine that there are many readers who have not heard of the direct conversion principle. Basically, the wanted signal is first selected by one or more tuned circuits, and may or may not be amplified with an RF amplifier. The signal is then fed into a mixer, together with a local oscillator signal. But in contrast with an ordinary superhet, where the oscillator frequency is offset by the value of the intermediate frequency, here the oscillator is on the same frequency as the signal. This gives a direct audio beat instead of an IF.

Let us take the concept a little further. Suppose that we wish to receive a CW signal. Any input tuned circuits will be tuned to the frequency of the wanted signal and the local oscillator will also be tuned to the frequency of the signal. If the local oscillator is set exactly to the same frequency as the carrier, we will have a "zero beat" condition, with no audio output from the mixer.

Suppose now that we offset the local oscillator (either high or low) from the frequency of the wanted signal by 1kHz. We will now get a beat frequency of 1kHz as output from the mixer. This output will be at low level and must be amplified in an audio amplifier system to drive a pair of headphones or a loudspeaker.

Again, suppose that we wish to receive a single sideband signal. This time, we must adjust the local oscillator frequency as closely as possible to the suppressed carrier frequency of the wanted signal. The sidebands received will now beat with the local oscillator and the mixer output will be the recovered audio of the signal. This needs to be amplified, as explained before.

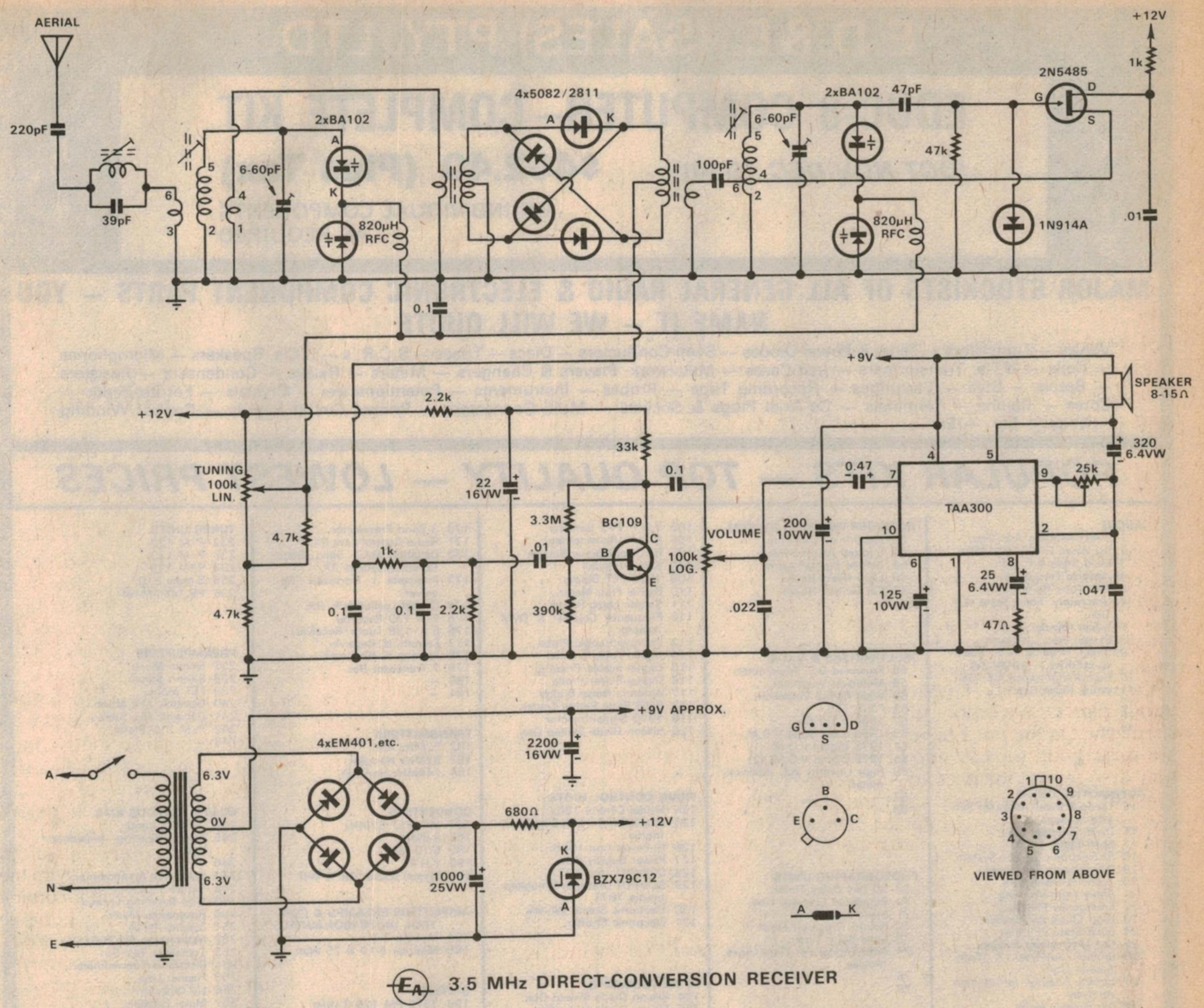
Let us take the explanation a little further and consider the possibility of receiving AM signals. Under these conditions, we must set the local oscillator to precisely the same frequency as the carrier of the incoming signal. This done, we are able to resolve the AM signal quite well. Unfortunately, it is very difficult to meet this stringent requirement. With the local oscillator offset from the incoming carrier, we get a beat frequency equal to the difference between the two. Also, beats against the sidebands are confused and the result is somewhat of a mess.

I have added the last paragraph on the possibility of AM reception so that there is not likely to be any disappointment with the performance of this type of receiver. While capable of resolving CW and SSB signals quite well, direct-conversion receivers are not as good for AM reception.

A look at the circuit will show better how the foregoing has been achieved. From the aerial, the signal is fed into a tuned circuit, consisting of a coil with three windings, one of which is tuned by two variable capacitance diodes, back-to-back. Signals from the tuned circuit are fed into a double-balanced ring mixer.

The mixer consists of two transformers wound on TV "balun" cores, with four hot-carrier diodes. Output from the mixer is from the two transformer centre taps. Injection from the local oscillator is into the second of the two transformers.

The local oscillator is a Hartley, with a junction FET as the active device. The tapped coil is tuned with a pair of variable capacitance diodes, as for the input circuit. A silicon diode between the FET



3.5 MHz DIRECT-CONVERSION RECEIVER

gate and ground is to restrict the amplitude of oscillation.

The tuned circuits are tuned by changing the amount of reverse voltage applied to the variable capacitance diodes. This is achieved by a potentiometer across the regulated 12V supply, the voltage from which is fed to each set of diodes via an RF filter consisting of two RF chokes and a 0.1uF capacitor. The 4.7k resistor on the tuning potentiometer is to assist in reducing cramping at the low frequency end of the dial.

Output from the mixer passes through a low pass R-C filter. The bandwidth of this filter actually determines the selectivity of the system. Consistent with simplicity, the filter constants give a fair degree of selectivity. The selectivity could be narrowed by making a more complex filter but this was considered not to be necessary.

The low level signal from the low pass filter is amplified in a single stage audio preamplifier. A volume control follows, the output of which is fed into a small IC audio amplifier, capable of driving a loudspeaker.

The power supply is a dual arrangement, from a small power transformer with a 12.6V CT secondary winding. Four silicon diodes are connected in a bridge across the transformer secondary. The bridge output gives about 18V DC, which is regulated down to 12V with a resistor and zener diode. Approximately 9V DC is obtained from the transformer centre tap to supply the main audio amplifier.

Before leaving the circuit, you may be wondering why I have not mentioned the 220pF capacitor and the parallel trap circuit between the aerial terminal and the first tuned circuit. The Q of the first tuned circuit is rather low and this lead to a couple of problems. The second harmonic of the oscillator could beat with strong unwanted signals which, although attenuated, came through along with the wanted signals. Of course, the signals were also at twice the frequency of the tuning. As an example, VNG on 7.5MHz could be tuned in at 3.75MHz on the dial.

COIL WINDING DATA

Trap:
50 turns 30B&S enamel close wound on Neosid 7.6mm x 32mm former with grade 900 slug.
Aerial coil:
100 turns 30B&S enamel close wound on Neosid 7.6mm x 58mm former with grade 900 slug. Output winding: 20 turns 30B&S enamel close wound over earthy end of tuned winding. Aerial winding: 10 turns 30B&S enamel close wound over output winding.
Oscillator coil:
100 turns, tapped 20 turns from earthy end, 30B&S enamel close wound on Neosid 7.6mm x 58mm former with grade 900 slug.
Mixer transformers:
Take three lengths 30B&S enamel wire and twist together to a pitch of about 6mm. Wind 15 turns and terminate as shown in diagram.

The trap was added, tuned to 7.5MHz, and this problem was solved.

If you happen to live to close to one or more broadcast transmitters, then there may also be trouble with them breaking through. The 220pF capacitor cures this one.

The problems just mentioned have arisen because the design has been simplified by as much as could be considered practical. Some improvements could be effected by introducing an FET source-follower between the tuned circuit and the input winding of the transformer for the mixer. The low impedance aerial coil winding presently feeding into the mixer would be omitted and the tuned winding itself would be connected to the source-follower, via a blocking capacitor.

By making the above modification, there should be some increase in gain. Also, the Q of the tuned circuit should be improved. However, this is not necessary and the unit as it stands is capable of quite a good performance.

Every effort has been made to be sure that the components used are readily available on the Australian market. However, to make it somewhat easier for the intending builder, a few comments on some of the components may be helpful.

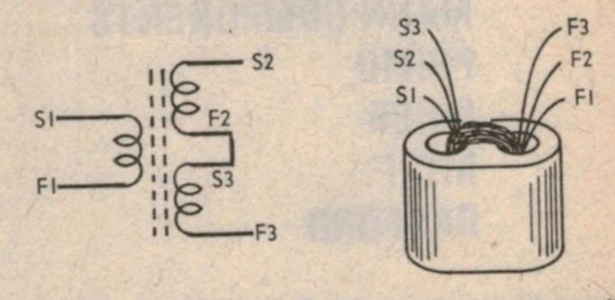
Resistors, capacitors and transistors should present no problems. We understand that there are also ample stocks of the TAA300 audio IC. Diodes for the power supply may be any brand equivalent to the type specified. The variable capacitance diodes are very important though, and the type BA102 must be used.

The hot carrier diodes used in the mixer are ideal for this application and should be used for best results. However, they are rather expensive and if you wish, the gold bonded germanium type OA47 may be worth trying. Even the common OA90 may be satisfactory. However, in the latter case, it may be necessary to increase the value of the 100pF coupling capacitor between the oscillator and the mixer.

The two RF chokes are not critical and any value between about 330uH and 1mH should be satisfactory. Apart from the coil former for the trap, the other two formers must be the Neosid type specified, as they must fit the printed board. While different types of formers may be satisfactory for the mixer transformers, we suggest that you use those which are normally intended for use on TV baluns.

The transformer which we used is a type PF2851 made by Ferguson. This is a readily available type, rated at 2.5VA. However, there are other similar types available which should be quite satisfactory. These include the newer line now offered by Ferguson, types PL12/5VA and PT12/5VA. If you wish to use the latter types then special mounting arrangements have to be considered, as they are intended for use on printed boards.

The printed board for the prototype was supplied by RCS Radio who will be making boards available, either direct or through your usual supplier. Alternatively, we imagine that other manufacturers will also be making boards available.

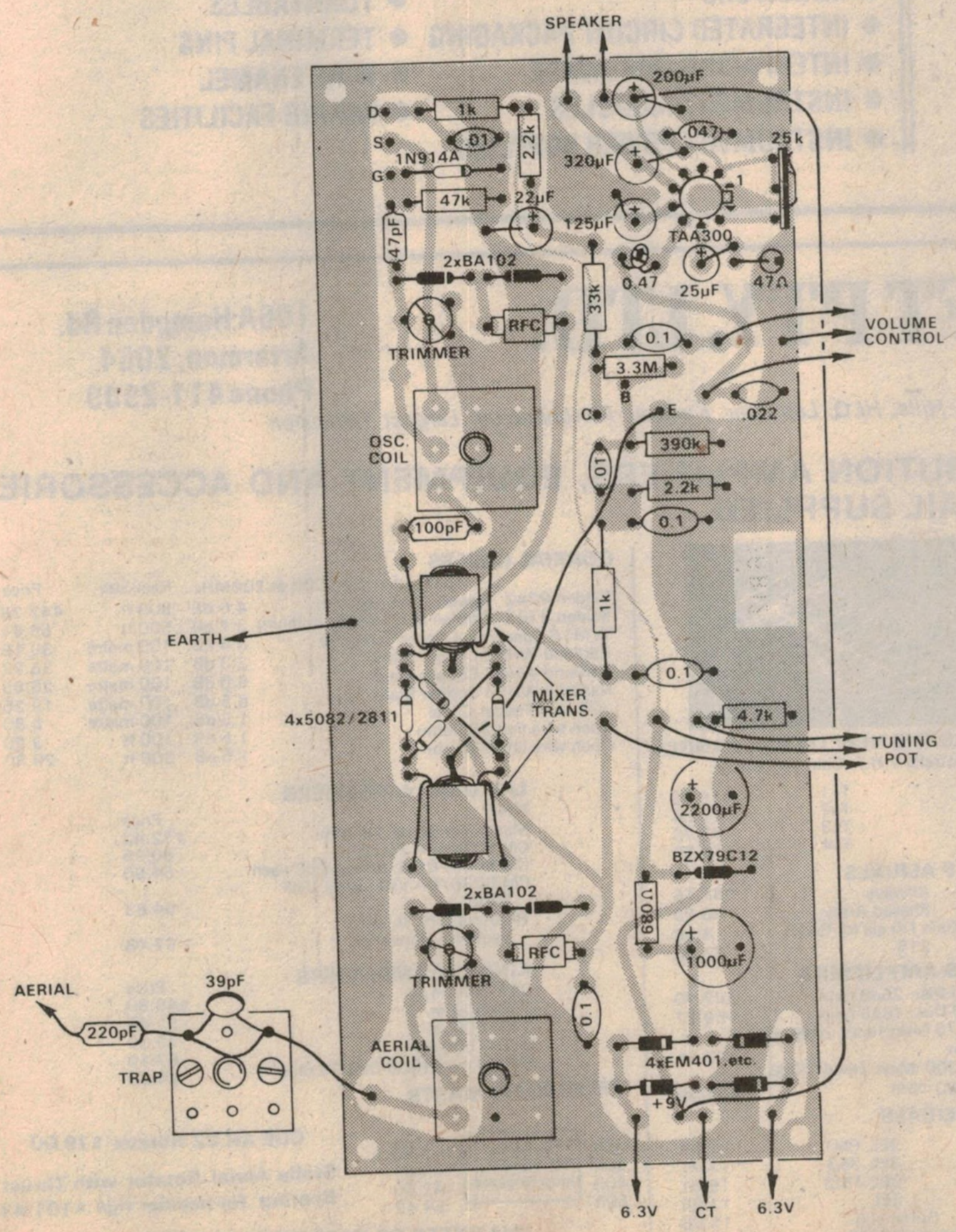


This diagram shows the wiring terminations for the two mixer transformers.

The dial arrangement consists of a drive mechanism and a scale. The drive is the well known planetary type sold under the Jabel brand and is available from Watkin Wynne Pty Ltd, 32 Falcon Street, Crows Nest 2065, or through your local supplier. The scale is simply a card calibrated and covered with a piece of sheet perspex. More will be said about the scale when alignment and calibration are discussed.

The case which we used was obtained from Radio Despatch Service, 869 George Street, Sydney, 2000. You may obtain a similar case from the above supplier, or you may be able to get a similar or other suitable type elsewhere. The case is a matter of choice but we strongly suggest that it be a metal one, to minimise the effect of body capacitance.

Construction of this little receiver is fairly straightforward. A good place to start is with the coils. These should be wound according to the information given in the table. The aerial and oscillator coils should be terminated according to the numbering given on the circuit, so that the windings match up with the



The component overlay diagram shows the PC board from the component side. Pay particular attention when inserting polarity conscious components.

printed board. Make sure that the oscillator coil is firmly wound to ensure a stable oscillator signal. Pins 4 and 6 should be bridged.

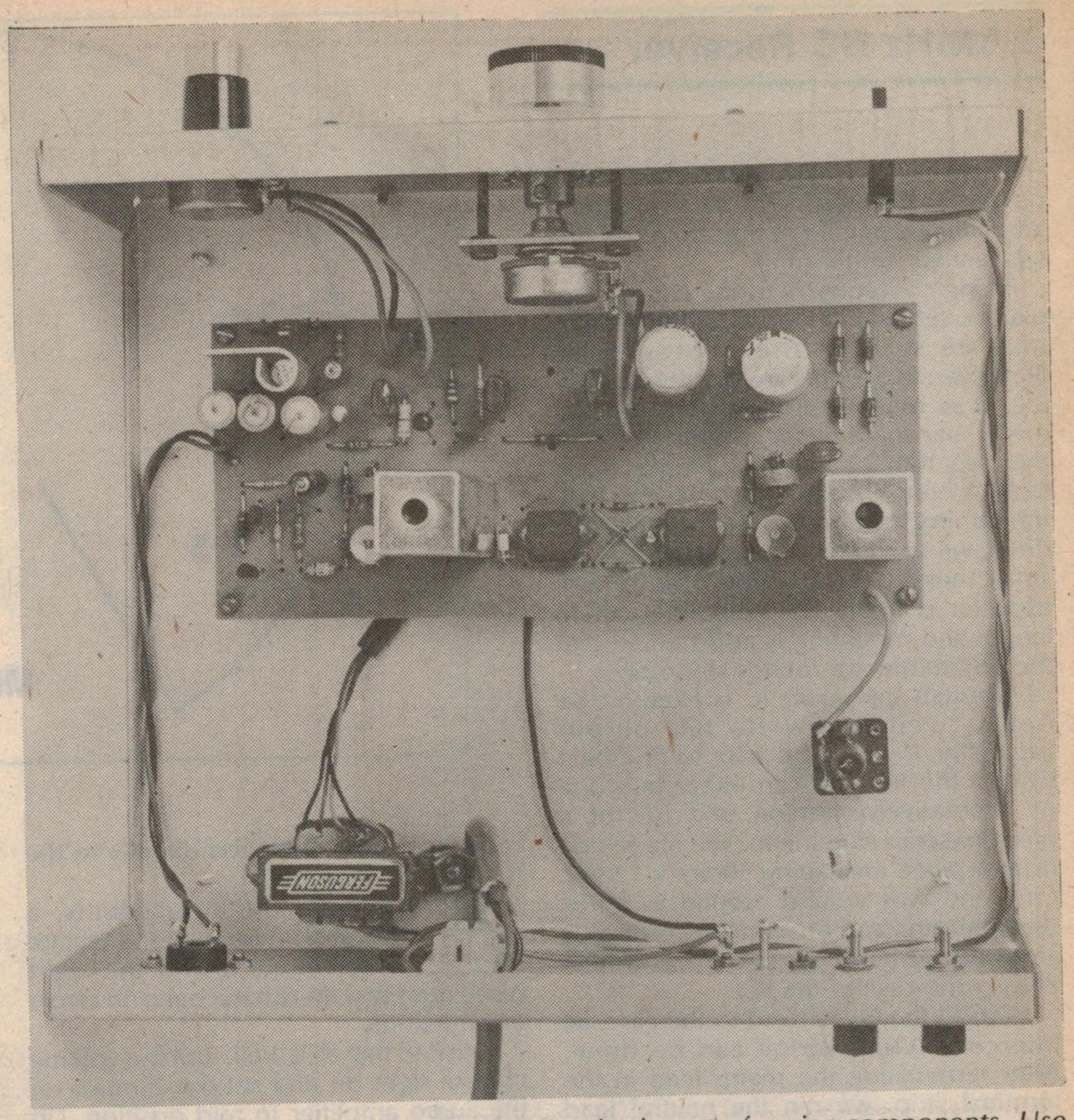
Winding the mixer transformers can be a little tricky. Make sure that you have sufficient length of wire, when twisted, to wind 15 turns. One turn constitutes a pass through both holes in the former. Keep the winding firm, otherwise you may have trouble getting on the 15 turns. On the other hand, the number of turns is not particularly critical and if you have space left, then you may add extra turns up to about 20 or so if you wish.

Having done the windings, the terminations have to be sorted out with a multimeter and the terminations done according to the drawing.

Assembly of the printed board is best done by fixing the small components first. Resistors and diodes go first, followed by capacitors, transistors, IC, and finally the coils. Make sure that all diodes, transistors and electrolytic capacitors are connected with correct polarity.

Before fixing the aerial and oscillator coils to the board, bend the can lugs over so that they interfere with the mounting screw holes. This ensures that when you screw the coil to the board, the can will be effectively earthed. Fixing the mixer transformers may be effected by using small pieces of double-sided adhesive tape, or simply by using a suitable glue, such as Tarzan's Grip.

When soldering components to the board, always have a good, clean, hot iron. Use a good quality resin cored solder and avoid overheating components. But at the same time, avoid "dry" joints.



An internal view of the prototype showing the layout of major components. Use this photograph in conjunction with the wiring diagram to aid construction.

Apart from the external leads to and from the board, there are two "jumpers" required. One is from the centre tap of the mixer input transformer. Run a piece of hookup wire from the copper pad under the board to the emitter connection of the BC549 preamplifier transistor. Another lead must also be run from the

PARTS LIST

- 1 Metal case, 230mm wide x 90mm high x 210mm deep
- 1 Jabel planetary dial drive, with pointer
- 2 Knobs
- 1 Switch, SPDT
- 1 Printed board, 78mm x 184mm, code 76R12
- 1 Power transformer, 240V primary, 12.6V CT secondary, 2.5VA
- 1 Terminal strip, 3-position
- 1 Speaker socket, 2-pin
- 1 Coax socket
- 2 Terminals, 1 red, 1 black
- 4 Spacers, brass, ½in long, tapped ⅛in Whitworth
- 4 Silicon diodes, EM401 or similar
- 4 Variable capacitance diodes, BA102
- 4 Hot-carrier diodes, 5082/2811 (see text)
- 1 Silicon diode, 1N914A or similar
- 1 Zener diode, BZX79 C12
- 1 Transistor, 2N5485 or similar
- 1 Transistor, BC549, BC209, BC109
- 1 IC, TAA300, with flag heat sink
- 2 RF chokes, 820uH
- 1 Coil former, Neosid 7.6mm x 32mm with grade 900 slug
- 2 Coil formers, Neosid 7.6mm x 58mm with can and grade 900 slug

RESISTORS (½W unless stated otherwise)

- 1 47 ohms
- 1 680 ohms
- 2 1k
- 2 2.2k
- 2 4.7k
- 1 25k trimpot
- 1 33k
- 1 47k
- 1 100k log pot
- 1 100k linear pot
- 1 390k
- 1 3.3M

CAPACITORS

- 1 39pF NPO ceramic
- 1 47pF polystyrene
- 2 6-60pF Philips trimmer
- 1 100pF polystyrene
- 1 220pF polystyrene
- 2 .01uF 100V greencap
- 1 0.22uF 100V greencap
- 1 .047uF 25V ceramic
- 4 0.1uF 100V greencap
- 1 0.47uF 35VW tantalum
- 1 22uF 16VW electrolytic
- 1 25uF 6.4VW electrolytic
- 1 125uF 10VW electrolytic
- 1 200uF 10VW electrolytic
- 1 320uF 6.4VW electrolytic
- 1 1000uF 25VW electrolytic
- 1 2200uF 16VW electrolytic

SUNDRIES

Hookup wire, solder, solder lugs, rubber grommet, 3-core flex, 3-pin plug, cable clamp, screws, nuts.

Note: Resistor wattage ratings and capacitor voltage 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 if available, providing ratings are not exceeded.

+9V point from the power supply, to the corresponding point at the audio amplifier output. Or, it may be run to the speaker socket terminal.

Fitting components to the case is simple enough and the location of the items may be seen in the photographs. However, two points are worth mentioning. It is most important that you use metal spacers to fix the printed board to the case. If this is not done there is likely to be a hum problem. Also, when fixing the tuning potentiometer to the dial drive, we used some long screws and a small metal plate to which the potentiometer is fixed. The spindle is cut to length and mounting is adjusted so that the potentiometer rotates smoothly.

Although the audio IC is likely to be run at well below its full output capability, it would be wise to fit a heat sink to the IC. You can either buy one or alternatively, fashion one out of a piece of scrap aluminium. We made one from a piece measuring 50mm x 12mm. One end was wound around a 5/16in diameter drill and the resulting loop was adjusted by hand so that it was a neat fit over the case of the IC.

With all the items fixed to the case, all interconnecting wiring can be done. After terminating the mains lead in the terminal strip, we ran the neutral lead direct to the transformer and the active via the switch on the front panel. The mains earth was taken to a lug under the coax aerial socket mounting screw. We ran a lead from the earth copper at the back of the board, to the same earth lug. The coax socket is connected to the other aerial terminal and the 220pF capacitor is swung across to the trap coil.

The 39pF capacitor is connected directly across the trap coil and the 4.7k resistor is also connected directly to the tuning potentiometer.

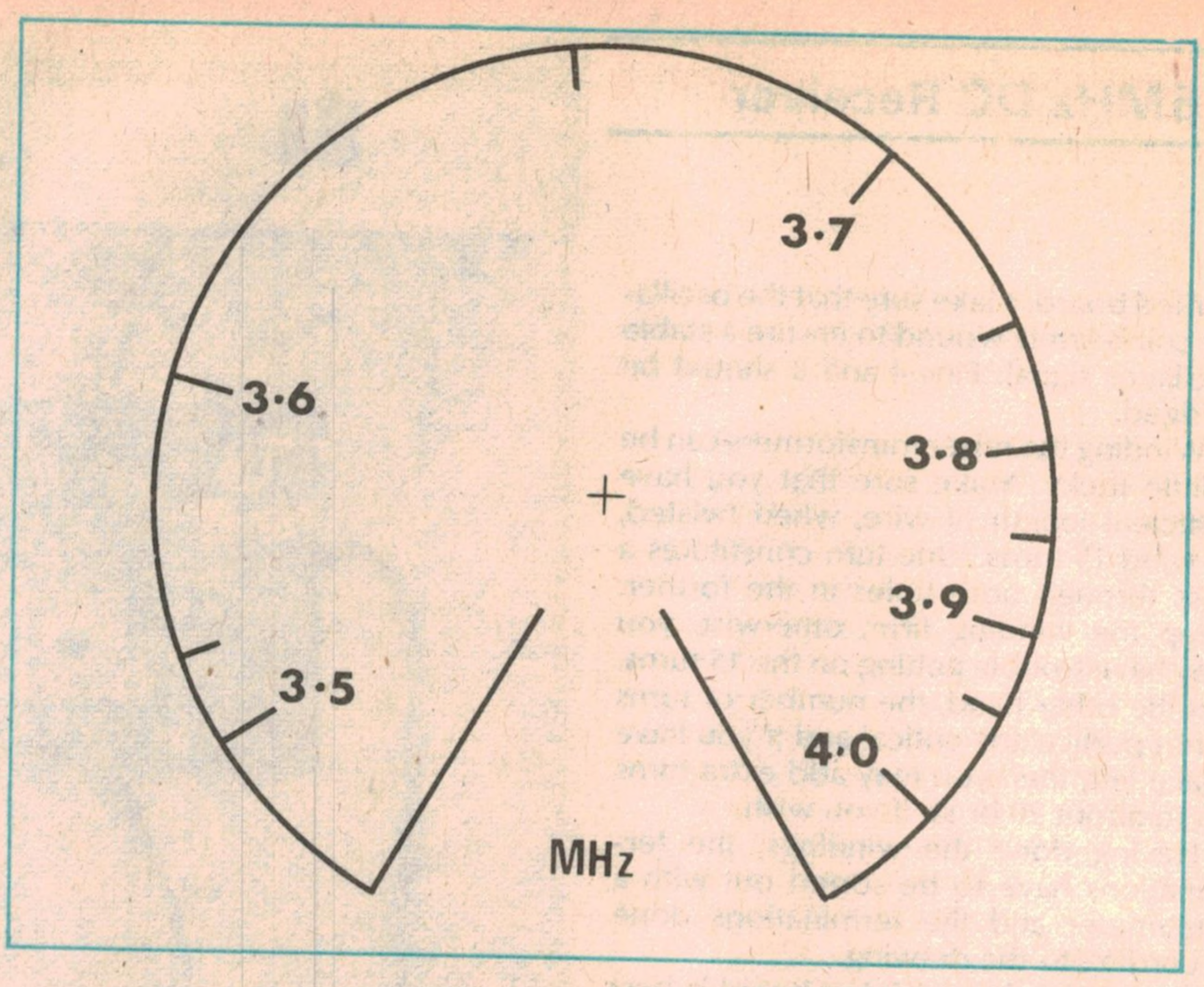
Before making the adjustments, a careful check should be made to ensure that all components are in the right places and that there have been no errors or omissions.

Satisfied that all is well, turn the volume control right off and set the trimpot on the audio amplifier to mid position. Lift the lead from the +9V supply point and insert a multimeter with it set to the 10mA range or higher. Switch on, and adjust the trimpot for a reading of 8mA. Then switch off and resolder the lead.

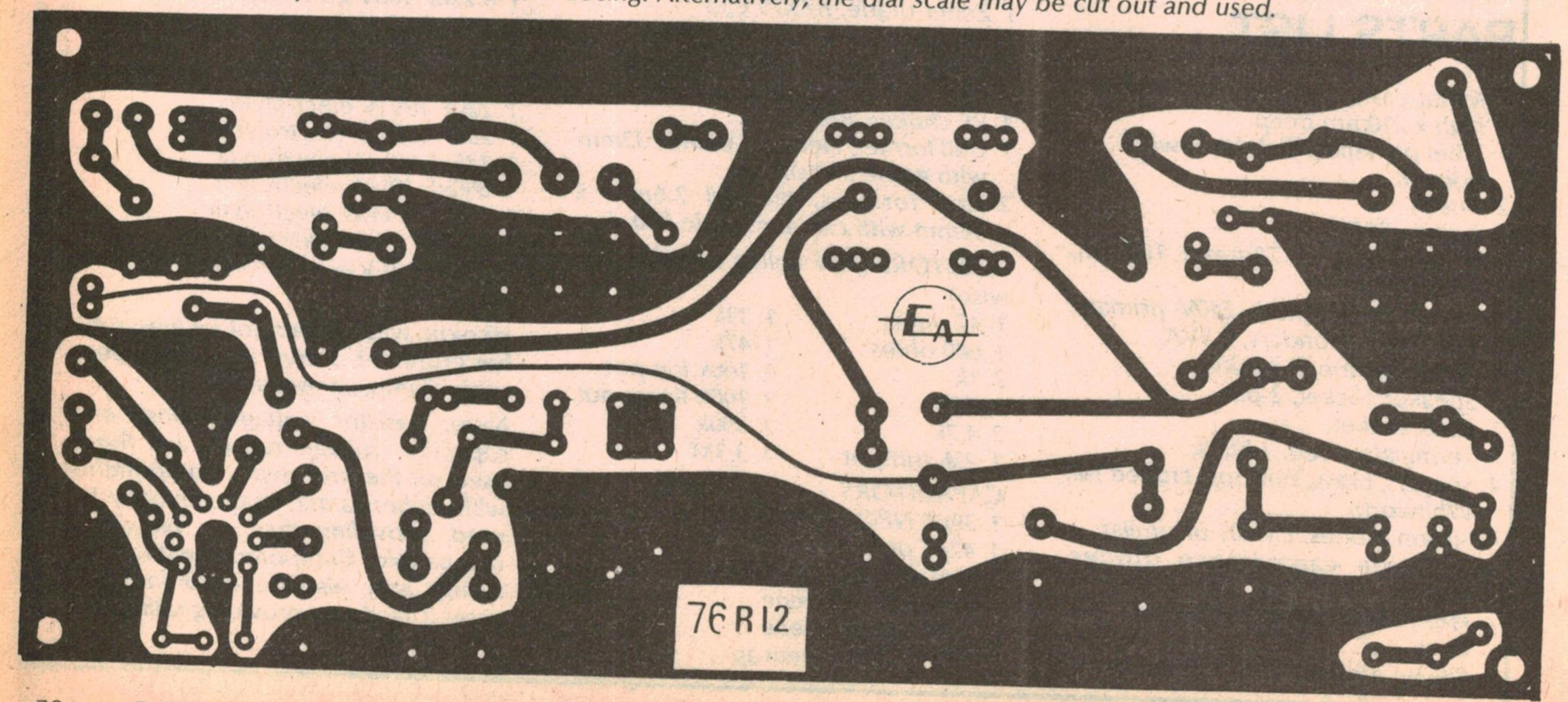
Although we have not mentioned it so far, a dial scale is needed and we have reproduced a full size copy of the one which was used on the prototype. Due to the variations associated with varicap diode tuning, more than likely your dial calibrations will not be the same as those of the prototype. However, the reproduced scale can be useful as a guide as to what to expect. Just how you settle on your dial scale will be up to each individual to decide.

Whatever you may decide, two points on your scale will correspond with those on the prototype. They are the 3.5MHz and the 4.0MHz points and these should be marked before calibration and alignment is done.

We will assume that you have access to a signal generator or some other means of identifying frequencies within



The dial scale (above) and the PC board pattern are shown here actual size to facilitate tracing. Alternatively, the dial scale may be cut out and used.

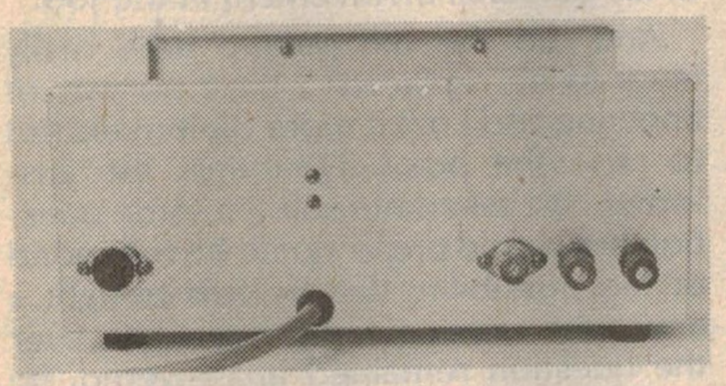


the range of interest. Set the generator to 3.5MHz and set the receiver dial to the same point on the dial. Switch on and adjust the slug in the oscillator coil until a signal is heard. Now adjust the slug in the aerial coil for maximum response.

Now set both the receiver and generator for 4MHz. Adjust the oscillator trimmer until a signal is heard. Then adjust the trimmer on the aerial coil for maximum response. In common with all alignment procedures of this nature, it is now necessary to go back and forth from one end of the scale to the other, each time making a smaller adjustment to the appropriate slug or trimmer until both end points are accurately set. Alignment is then complete.

Although alignment is finished, we still have to do something about calibration. If you have a copy of the original in place, then by means of the generator or some other source of known marker frequencies, check each of the points along the scale. If you are lucky they may be close enough, and you may elect to use the copy of the original scale. On the other hand, you may decide to set your own calibration points.

You will have noticed that the scale



A view of the rear panel. The speaker socket is at left, with the aerial socket and terminals to the right.

calibrations are not linear. This is due to the characteristics of the tuning diodes and other constants relating to them in the tuning system, and is difficult to avoid, short of taking rather elaborate steps.

With your direct conversion receiver now operational, you will need a good aerial system for best results. Preferably, the aerial should be one cut for the 3.5MHz band, with a properly matched coax feeder. Given this, the little receiver should give a good account of itself on signals from amateurs, etc, operating on CW and SSB, within the tuning range.

If you find that you are having trouble with signals transmitting in the range between 7MHz and 8MHz breaking through and being tuned along with the wanted signals, then the trap in the aerial circuit needs adjustment. As an example you may be receiving the standard time and frequency station VNG, actually on 7.5MHz, on 3.75MHz on your dial. If this is the case, tune in the unwanted signal and adjust the slug in the trap for minimum response. By adjusting the trap here in the middle of the band, it should be effective right across the tuning range.

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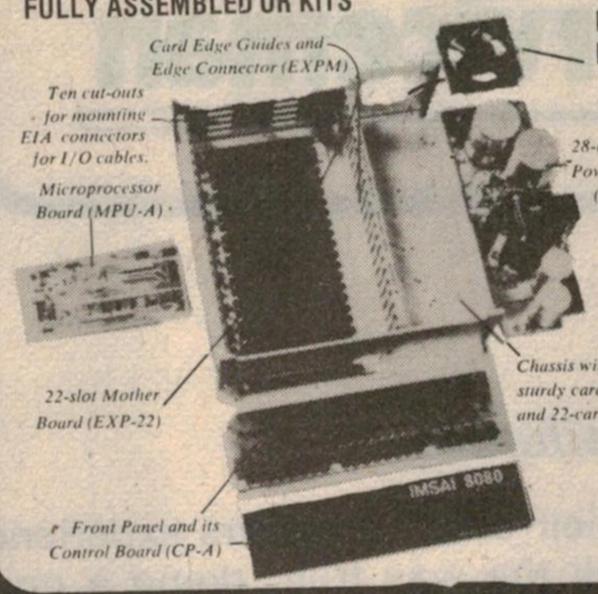

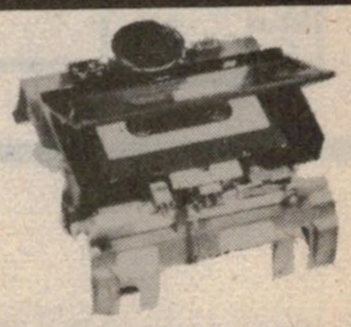

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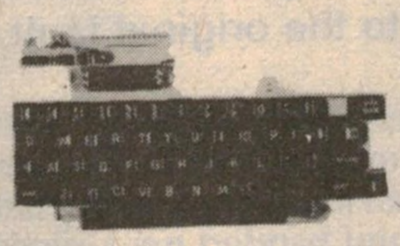

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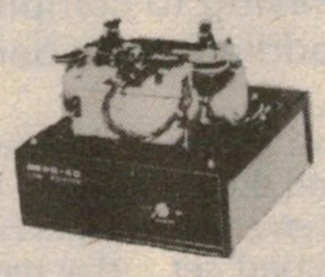

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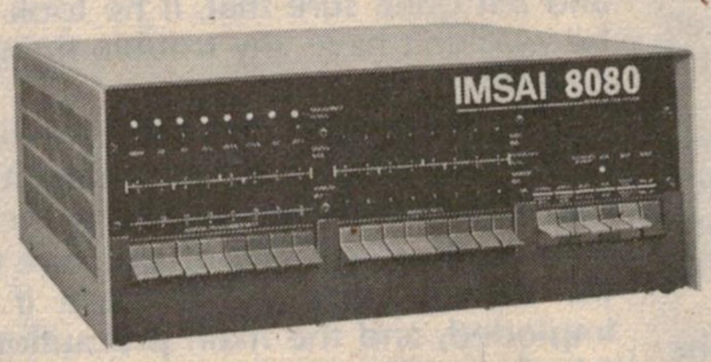

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