Receiver/Tunable IF for HF or VHF bands

Here is a project which although designed especially for radio amateurs working on the VHF bands, would also be ideal for anyone seeking an easy to build basic shortwave receiver. The circuit is fully solid state, and built almost entirely on printed wiring boards to simplify assembly.

by IAN POGSON

The unit to be described is basically a short-wave receiver tuning from 3.5MHz to 7.5MHz. The objective was to design a unit which was economical, consistent with good performance, and still be as versatile as possible. On its own, it may be used to tune both the 3.5MHz and 7MHz amateur bands, as well as the frequency range in between these bands.

We are presenting it equipped with a mains power supply but provision is also made for battery operation. As the total quiescent current drain is only about 25mA, eight type 950 cells may be used to power the receiver purely for portable use. In addition, it may also be powered from a 12 volt car battery, with either positive or negative earth connection.

The tuning range was selected not only because it covers two of the very popular amateur bands and the interesting space in between, but because it also offered a good compromise range for use as a tunable IF for VHF converters. This may well be its primary role.

Originally, it was intended to provide only for AM reception but when the VHF bands are considered in depth, the fact emerges that many amateurs use FM. So it was decided that this should be included if at all possible. After due consideration, it was decided that the best way to provide the FM facility would be to make up a separate board with an FM IC unit. Provision has been made for this to be added, we hope in the near future.

Although we do not have much in the way of concrete plans for describing converters for use with this receiver in the immediate future, we are hoping to look into the possibility of coming up with solid state converters for 52MHz and 144MHz, as well as 14, 21 and 28MHz. This would give a complete set of receiving facilities for all the most popular amateur bands.

We can almost hear the question already: what about SSB reception? We set out originally to produce as simple a tunable IF unit as could be considered reasonably possible, and to incorporate SSB reception facilities normally complicates any receiver quite a bit. However, if the demand appears to warrant it, we would certainly take another look at the possibility of adding a BFO at least. Meanwhile, we are confident that this little receiver will neet the needs of many readers.

With the exception of the power supply, the smaller components of which are wired to a piece of miniature tag board, the rest of the receiver circuit is included on printed wiring boards. This makes assembly and wiring about as easy as it could be, with the very good possibility of being able to duplicate the performance of the original, with a minimum of trouble.

In accordance with our ideas of overall simplicity, we have adopted a rather different approach to the hardware, compared with receivers which we have described in the past. The metalwork is an adaption of that used for some of our audio equipment.

The circuit reveals that the receiver is relatively simple for the task it performs. The first stage is a mixer with a tuned circuit input, preceded by a simple 2.5K potentiometer aerial attenuator. The associated oscillator is a well tried design and very stable. Injection into the emitter of the mixer is via a small winding on the oscillator coil. This method is very efficient and the mixer-oscillator combination is somewhat easier to get going than a self-oscillating mixer.

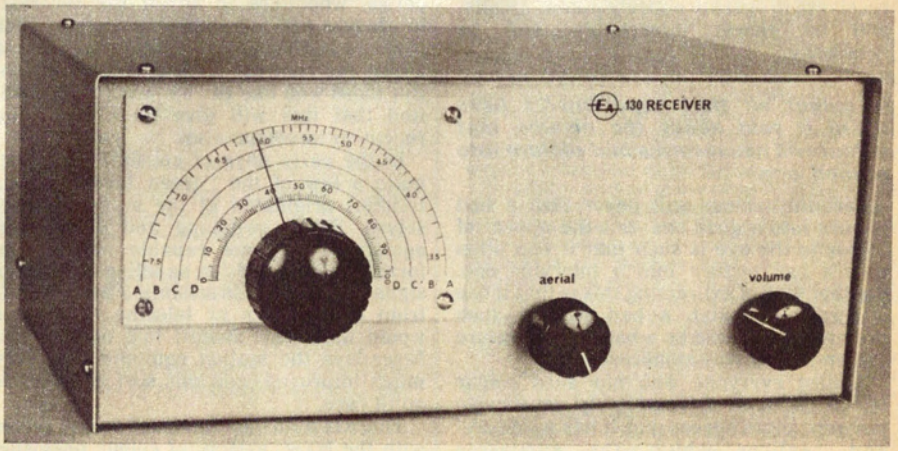
Output from the mixer is coupled into the first IF stage via a single tuned IF transformer. Coupling between the first and second IF stages and between the second IF amplifier and detector is via Murata SFD-455B ceramic filters. The detector is a transistor operated "class B", and as well as being an efficient detector, it also provides a source for the AGC system.

Providing a good AGC system for use with transistors can present quite a problem, unless one is prepared to go to rather elaborate circuitry with little regard to cost. We have steered what we consider to be a middle course and the results have turned out to be very satisfactory. Each of the two controlled IF amplifiers has a special control transistor in its emitter circuit and for the slight extra cost of the two transistors, the results are worthwhile.

The base of each of the control transistors is biased from the collector of the detector such that they are "bottomed" when no signal is present. When a signal is received, collector current of the detector increases according to the strength of the signal. This causes a voltage drop at the collector and so less current is available for the bases of the controlling transistors. As a consequence, these transistors tend to draw less current and effectively increase the resistance in the emitter of each IF amplifier. This leads to degeneration and a consequent fall in amplifier gain.

Due to the fact that the detector is used as a source of AGC, rather than adding a separate AGC generator system, the two stages of control still leave something to be desired. This system has therefore been supplemented by the technique of using a germanium diode to damp down the tuned winding of the IF transformer under very strong signal conditions. With this addition, the AGC system is able to handle a very wide range of signal strength with only a relatively small increase in audio level.

The audio amplifier is a slightly modified version of that used in our Transistor Intercom unit, described in August, 1971. The modifications are such that the amplifier may be used with a supply rail anywhere between 10 and 20 volts. The supply may even be reduced to as low as nine volts with a tolerable amount of crossover distortion.



From this picture of our tunable IF unit, it may be seen that it is quite simple. Metalwork should be available commercially for those who want it. Dial scales ready calibrated are available through our Information Service.

The circuit at right is interesting on a number of points. The use of ceramic filters, the simple but effective AGC system, a highly stable VFO, and provision for battery operation.

This has all been achieved by suitable adjustment of bias arrangements together with a limitation set on the supply to the first stage of 12 volts with a zener diode. It should be added that the preamplifier used in the intercom has been omitted.

The power supply is also quite simple, consistent with adequate voltage regulation where required. Supply to the audio stages is unregulated, with 12 volts regulated for the tuner, except for the oscillator. This has its own regulated supply of six volts. A highly stable supply is required here in the interests of frequency stability. A readily available 12.6V transformer is used, followed by a bridge rectifier, with filter, dropping resistors and zener diodes. Switching facilities are also offered for readers who wish to combine mains and battery operation.

Construction is rather different from previous receivers of this type which we have described. As we have already mentioned, printed boards are used for component assembly and wiring instead of tagboard or similar methods. Also, instead of the more conventional chassis, panel and separate metal case, we have adopted the technique which we have been using for some years for our audio amplifiers, etc. This all contributes to produce a receiver which is economical and simple to build.

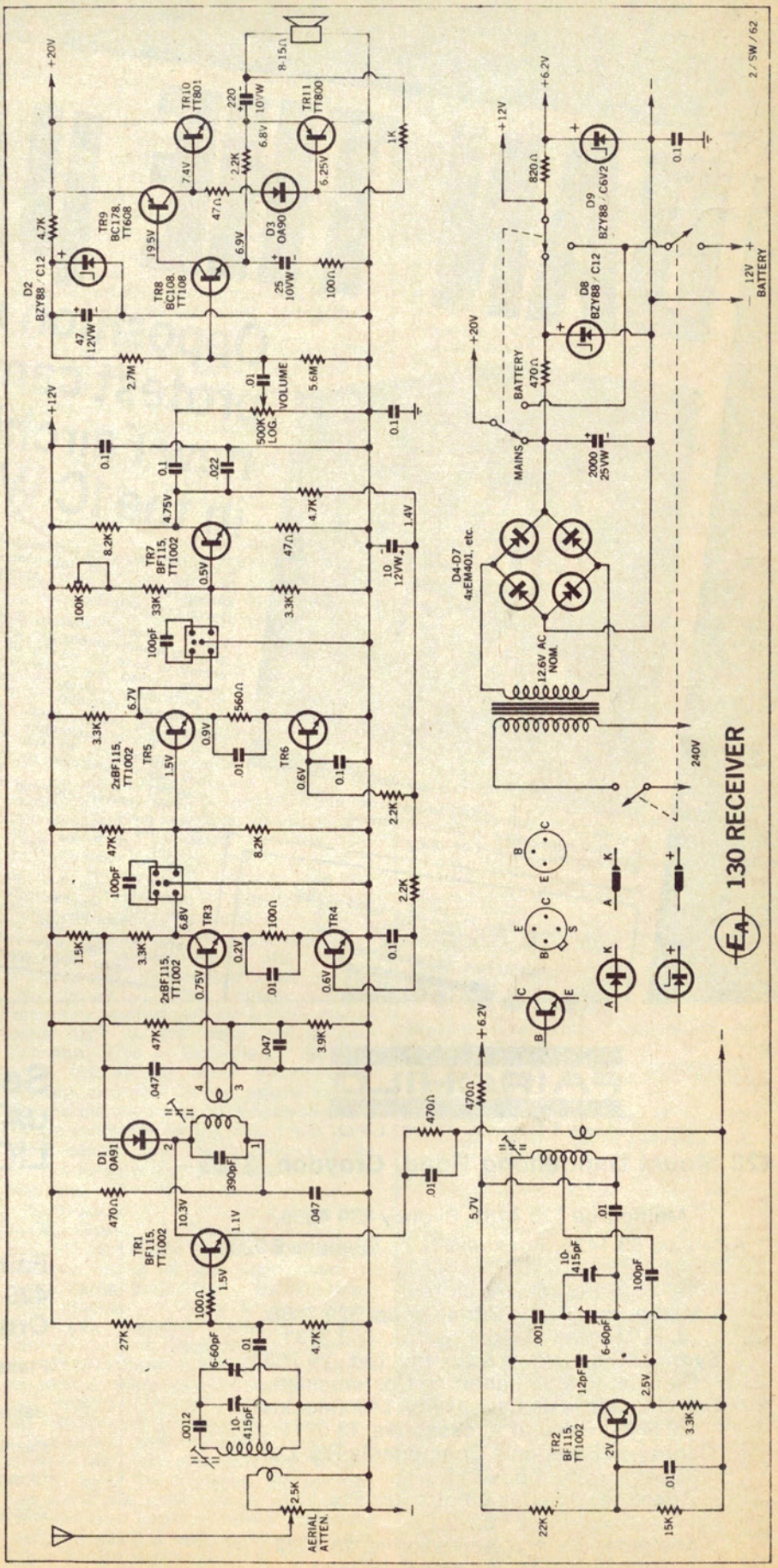
The metalwork consists basically of two "U" shaped pieces. One becomes the bottom, front panel and back panel, with all the boards and other components being mounted thereon. The other piece is a cover for the top and two ends.

The layout of the front panel naturally had to conform with internal requirements and still had to be easy and convenient to operate. The dial is located at the left, with aerial attenuator, volume control and switches located to allow for ease of operation. Space is also available for readers who may wish to add an "S meter" and more will be said about that later on.

Looking behind the front panel, it may be seen that the tuner board is immediately behind the panel and to the left. This leaves sufficient room for the audio board to be fitted to the right of the tuner board. At the rear left is the power transformer, with the wiring board carrying the rest of the power supply on the back panel. This leaves ample space on the base plate for possible future addition of an FM IF board and / or a BFO. Input and output sockets and power supply changeover switch are mounted on the back panel.

Perhaps the best place to start with the construction, is with the various sub-assemblies. There are two coils to be wound and these may be first on the list. The aerial coil consists of a primary and secondary winding, and the secondary is wound first. This consists of 45 turns, tapped at 11 turns from the bottom, of 26B&S enamel wire. The start and finish of this winding may be anchored in position with a small piece of adhesive tape. This is slipped under a few turns at each end during winding. The end protruding is then folded over the top of the winding when completed.

The tap on the coil may be effected in a number of ways. One simple method is to



scrape the enamel from about ⅛in of the wire at the tapping point. Another short piece of the same wire is soldered on to act as a lead. To avoid a short circuit, another small piece of adhesive tape should be placed under that turn at the tap. The primary winding of 7 turns is wound over the bottom end of the secondary, after having placed a piece of tape over that part of the secondary. Again, tape is used to anchor the winding in place.

To ensure that the windings stay firmly intact, they should now be given a coat of cellulose lacquer or other suitable material. When dry, the leads should be terminated such that when the coil is fitted to the board, the leads correspond with the relevant parts of the circuit. This is shown in the diagram.

The oscillator coil is treated in the same manner as the aerial coil, bearing in mind that the frequency stability of the receiver largely depends on this coil. It should therefore be wound firmly and finished in a workmanlike manner. The terminations are also given in the diagram.

Before the 2-gang variable capacitor can be fitted to its board, leads must be soldered to the two bottom lugs of the fixed plates. About three inches of 20 gauge tinned copper wire should be used, with a loop wound firmly around each lug before soldering. This will prevent the soldered joint from coming adrift when the other end of the lead is finally soldered to the board.

Components for the power supply, except the transformer, are wired to a miniature tag board according to the wiring diagram. The mains leads are terminated on the board and then run to the switch and on to the transformer primary. The switch to change over from mains to battery operation is also wired according to the diagram but the lead which goes to the +12V battery does not terminate on the board, being run directly from the appropriate terminal on the socket.

While we are on the subject of switches, it should be noted that there is a double pole switch on the volume control potentiometer, one pole of the switch is used for breaking the mains and the other pole is used for the battery.

When a battery is used, the mains lead will be removed from its socket, and vice versa. Readers who do not wish to use the battery facility, may omit the switch and simply make the necessary modifications to the wiring. The battery socket on the back panel will also be omitted. On the other hand, for those who wish to use batteries only, the mains transformer with its socket, together with the rectifier diodes, the 2000uF capacitor and the 12V zener may be omitted and the wiring modified to suit.

Before attempting to assemble the audio amplifier board, it should be noted that this board was designed for other projects and as this receiver is designed to operate from either a positive or negative grounded car battery, it is necessary to remove a little of the copper from the board before assembly. The copper to be removed comprises the small area around each of the two mounting holes. Sufficient copper must be removed with a razor blade or other suitable instrument, such that when the board is mounted to the metal cabinet, the screws do not make contact with the copper on the board.

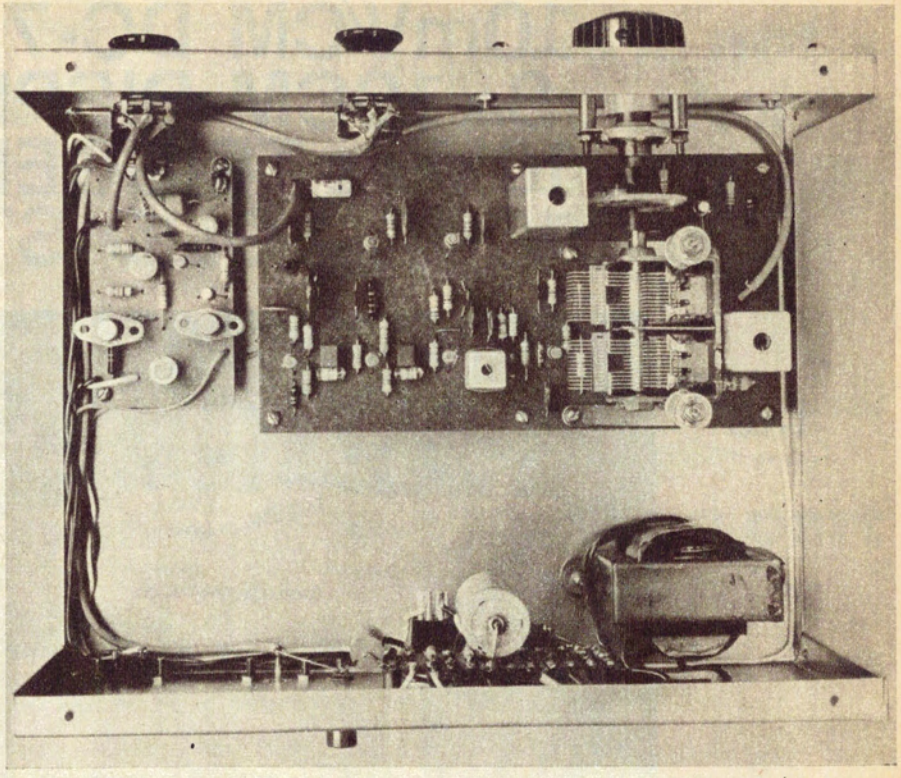
The space provided on the board for a preamplifier is not required for the receiver, and is therefore left blank.

An addition to the audio board specially for this receiver is the 12V zener diode, and we added ours on the copper side of the board, just underneath the 47uF electrolytic capacitor. Another point worth noting is that we used a pair of output transistors which are no longer available in the physical form as shown in the picture. Our transistors have a mounting flange, but these are not required in this circuit and the transistors are otherwise identical to ITT types TT801 and TT800. Apart from these points, the board is quite straightforward.

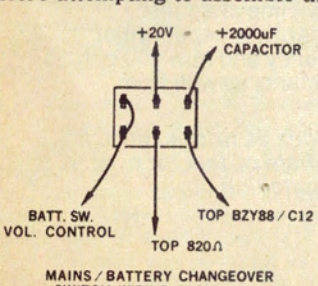
The largest and perhaps the most interesting sub-assembly is the tuner board. Although this board is also fairly straightforward, it is advisable to approach construction in a systematic manner. A logical place to start would be to fix all resistors and follow up with capacitors and other small items, including the transistors. These are followed by the IF transformer, variable capacitor and finally the two large coils in cans. These coils must be carefully sited with respect to lead terminations and function.

A trimmer must be soldered to each section of the variable capacitor and as may be seen in the picture, we used the old type Philips "beehive" trimmers. These are still available from a number of sources but if you are unable to get this type, or if you prefer the new solid dielectric type, then by all means use them. Care should be taken when soldering the latter units in place, making sure that a good soldered joint is made in each case, without damaging the trimmer by burning or overheating.

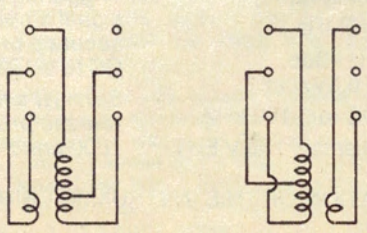
Having made ready all the sub-assemblies, these may now be fixed to the main case. To make the job easy, assembly should be done in a logical sequence. This is how we did it. The aerial terminal and all sockets are fitted to the back panel, followed by the mains transformer. Leads of sufficient length are soldered to the change-over switch, according to the diagram. The switch is then mounted such that when the toggle is pointing to the appropriate input socket, mains or battery, this is the mode of operation selected.



This view of the interior shows clearly the layout of the various sections. Note particularly the placement of the power supply board and sockets on the rear panel.

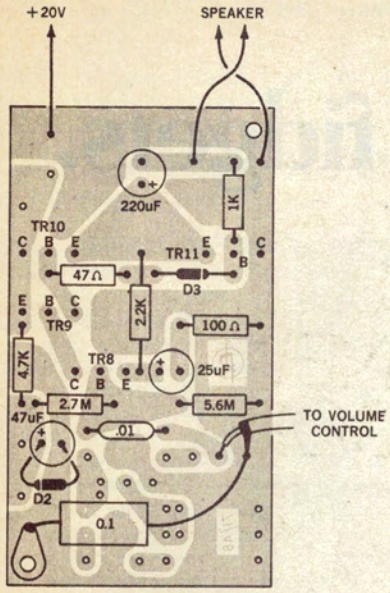


MAINS/BATTERY CHANGEOVER SWITCH WIRING FROM REAR

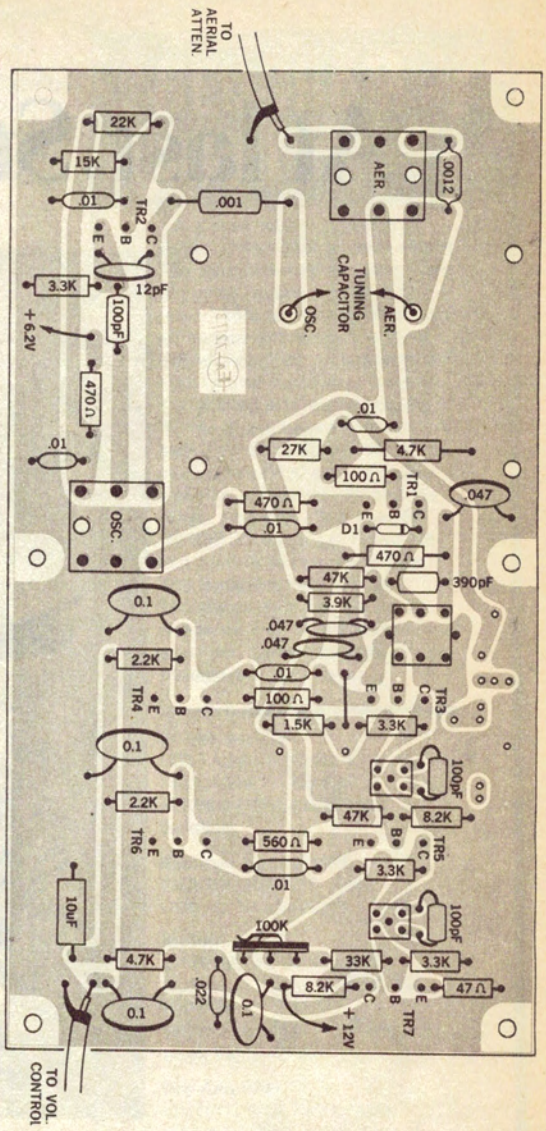


COIL CONNECTIONS VIEWED FROM ABOVE

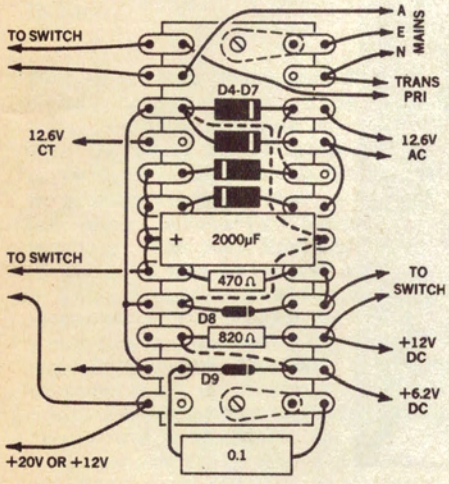
As the switch for selecting mains or battery operation is rather tricky to wire, a sketch is shown at left. Terminations for the aerial and VFO coils are shown at right.



The audio board is quite easy to assemble but it should be noted that a zener diode is mounted on the copper side. For normal operation, heat sinks should not be required for the output stage.



The tuner board is shown at the right and like the audio board, is shown from the component side, with the copper shown "ghosted". The unused holes are for the addition of an emitter follower later on.



The power supply panel is simple enough to follow but due care should be given to accuracy and the fact that the negative line is not earthed to the main frame.

The power supply board is mounted on the back panel and when doing so, care should be taken to ensure that the terminal on the board for the mains earth is securely connected electrically to the case. A shakeproof washer under the mounting screw will help here. Interwiring between the components already mounted may now be done.

Before fixing the audio board in place, make sure that leads are provided for the speaker socket, 20V supply, negative lead and shielded lead for the volume control. The board is now fixed in place, together with the volume control on the front panel. At this stage, and at frequent intervals during wiring, checks should be made to ensure that the negative supply line does not become shorted to the main case. Wiring between the audio board and other points may now be done. At this point and after a thorough check, power may be applied to see if all is well. A finger applied to the input to the volume control should show that the audio section is working.

The aerial attenuator is screwed to the front panel and then the tuner board mounted. This must have external leads fitted for the 12 volt and 6 volt supplies and shielded leads each to the volume control and aerial attenuator. With the board screwed into place, these leads are connected up. A shielded lead is then run from the aerial attenuator to the aerial coaxial socket, which is also connected to the aerial terminal.

When wiring in the shielded leads, do not connect the shield braid of any lead to the metal cover of the control. The shields should be connected to the appropriate lugs on these controls, however. Also, the shield of the aerial lead to the coaxial socket should be cut off at this end and not terminated. These precautions are necessary to allow the receiver to be used with battery supplies having either polarity grounded.

The dial assembly is mounted on the front panel with four screws and concurrently with this operation, the drive is lined up with the flexible coupling to the gang. A short piece of steel or brass ¼in diameter rod will be needed between the dial drive and the coupling. The coupling should be carefully tightened to the shafts, making sure that there is no strain and with the dial pointer at 100 when the gang is fully closed.

In addition to the 0.1uF capacitor between the negative line and the case mounted on the power supply board, we have found it also desirable to add another one on the audio board. This is connected from the negative line where the audio input shield is connected, across the other side of the board to a lug under the fixing screw, which in turn connects it to the case.

It may be noted at this stage, after mounting all the main components into the case that there is quite a bit of spare space. This has been provided so that additions such as an FM assembly may be added later and possibly other additions which we or readers may see fit to add in the future.

More than likely, manufacturers such as Heating Systems Pty Ltd will make metalwork available and this should be available through the normal channels. In some instances, four dimples are pressed into the bottom of the case but if these are not provided, then four small rubber feet may be fixed to the bottom of the case, near each corner.

At this stage, the receiver is virtually finished and before final adjustments are made, all wiring should be carefully checked to make sure that there are no mistakes or omissions. This applies particularly to switching and plug and socket connections. Another point to check and one which we mentioned earlier, is that the

PARTS LIST

1 Chassis, 10½ in wide x 8¼ in deep x 4½ in high
1 Cover to suit
4 Rubber feet
1 Power transformer, 240V to 12.6V, PF1728, PF2565, PT2150 or similar
1 Dual ratio dial assembly (Jabel)
1 Toggle switch, miniature DPDT
1 Coaxial socket
1 Aerial terminal
1 Plug and socket, Bulgin P360 3-pin
1 Plug and socket, Bulgin P73 6-pin
1 2-pin miniature speaker socket
2 Knobs
1 ¼ in x ¼ in insulated flexible coupling
1 ¼ in dia x ¾ in long brass or steel shaft
1 Miniature tag board, 12prs tags
10 Brass spacers, ½ in long x ¼ in dia, tapped ⅛ in Whit.
1 Printed board, 7½ in x 4in, 72 / T3
1 Printed board, 3 ⅝ in x 2in, 71 / A8
2 Neosid coil formers, 7.6mm x 2½ in, with grade 900 slug and can
1 Aegis ST45C IF transformer
2 Murata ceramic resonators, type SFD-455B

SEMICONDUCTORS

7 Transistors, BF115, TT1002, etc
1 Transistor, BC108, TT108, etc
1 Transistor, BC178, TT608, etc
2 Transistors, TT801, TT800 or AY6108, AY6109 (matched pair)
4 Diodes, EM401, etc
1 Diode, OA90
1 Diode, OA91
2 Zener diodes, BZY88 / C12
1 Zener diode, BZY88 / C6V2

RESISTORS (½ W unless stated otherwise)

2 47 ohms	1 560 ohms
3 100 ohms	1 820 ohms
4 470 ohms	1 1K
1 1.5K	1 22K
3 2.2K	1 27K
4 3.3K	1 33K
1 3.9K	2 47K
3 4.7K	1 2.7M
2 8.2K	1 5.6M
1 15K	

1 2.5K linear potentiometer
1 100K tab potentiometer
1 500K log potentiometer with DPST switch

CAPACITORS

1 12pF NPO ceramic
2 60pF Philips trimmers
3 100pF 630V polystyrene
1 415PF Roblan 2-gang variable
1 .001uF 400V polyester or polystyrene
1 .0012uF 400V polyester or polystyrene
7 .01uF 100V polyester
1 .002uF 100V polyester
3 .047uF 25V ceramic
4 0.1uF 25V ceramic
2 0.1uF 160V polyester
1 10uF 12VW electro
1 25uF 10VW electro
1 47uF 12VW electro
1 220uF 10VW electro
1 2000uF 25VW electro

MISCELLANEOUS

Hookup wire, 1 yd light coax cable, solder screws, nuts, solder lugs, power flex and plug, etc.

Note: Resistor wattage ratings and capacitor voltage ratings are those used for our 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, providing the ratings are not exceeded.

negative line of the system is isolated from the case.

Satisfied that all is well so far, power may be applied and an inspection made for signs of distress. It may also be a good idea at this stage to check the three voltages from the power supply. The 100K potentiometer in the bias circuit of the detector may be set tentatively to give a reading of 4.75V at the collector. This adjustment will subsequently be adjusted to give best results on a weak signal.

Before proceeding with the alignment, a word or two about the dial scale. The dial assembly used on the prototype is marketed by Messrs Watkin Wynne. The dial has a logging scale calibrated from 0-100 and there are also four blank scales. We have calibrated one of the blanks according to the basic range covered, ie, from 3.5 to 7.5MHz. Copies of this scale may be had through the Information Service for $1.00 each. The alternative would be to calibrate your own during the alignment process. We should also add that when this receiver is used as a tunable IF for converters, then the remaining blank scales may be calibrated to suit.

Alignment is best carried out with the aid of a signal generator. Set the generator to 3.5MHz and connect the output to the aerial terminal. Set the dial on the receiver to 3.5MHz, or 95 on the logging scale. Adjust the slug in the oscillator coil so that the signal is heard. Then adjust the slug in the aerial coil for maximum response and adjust the slug in the IF transformer for maximum response. During this process, the output of the generator should be progressively reduced and kept at such a level as to simulate a fairly weak signal.

Set the generator to 7.5MHz and the receiver to 7.5MHz, or 5 on the logging scale. Adjust the trimmer on the oscillator section of the gang until the signal is heard

(Continued on page 125)

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and then adjust the trimmer on the aerial section of the gang for maximum response. As is always the case with the alignment process, the procedures for 3.5 and 7.5MHz should be repeated until alignment is complete.

If a generator is not available, then a good idea is to do the job of alignment at night when the standard time-frequency station VNG is on the two frequencies of 4.5 and 7.5MHz. An aerial should be connected and the procedure followed much the same as that just described, except that 4.5MHz is used instead of 3.5MHz.