25 WATT UHF POWER AMPLIFIER

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The powers that be are often just not quite enough when it comes to radio transceivers. "Are you receiving me?" Loud and clear with the help of this ETI project to boost your transmitting signal to a very audible 25 watts.

HOW DO YOU feel about your transceiver radio not being able to deliver the full legal output power? Have you ever wanted to stretch your transceiver power to its legal limit? I guess you might think the idea is great but sounds a little too complicated. Having to modify your expensive transceiver radio is always difficult — and risky! What if you can't put everything back to where it was, after pulling your transceiver apart? Of course if it blows up, you can always buy a new one with higher output power.

For those of you who are radio communications enthusiasts, the following could be great news for you. Without changing anything in the transceiver, you can boost the output power to 25 watts! All you need is the ETI 743 — UHF amplifier to simply plug the antenna and your transceiver output into. And the cost in building this project is minimal when compared to buying another transceiver set.

Credit for the design is due to Gary Crapp and Gill MacPherson from Dick Smith Electronics. The project is available in a kit form, with parts from Dick Smith Electronics and others.

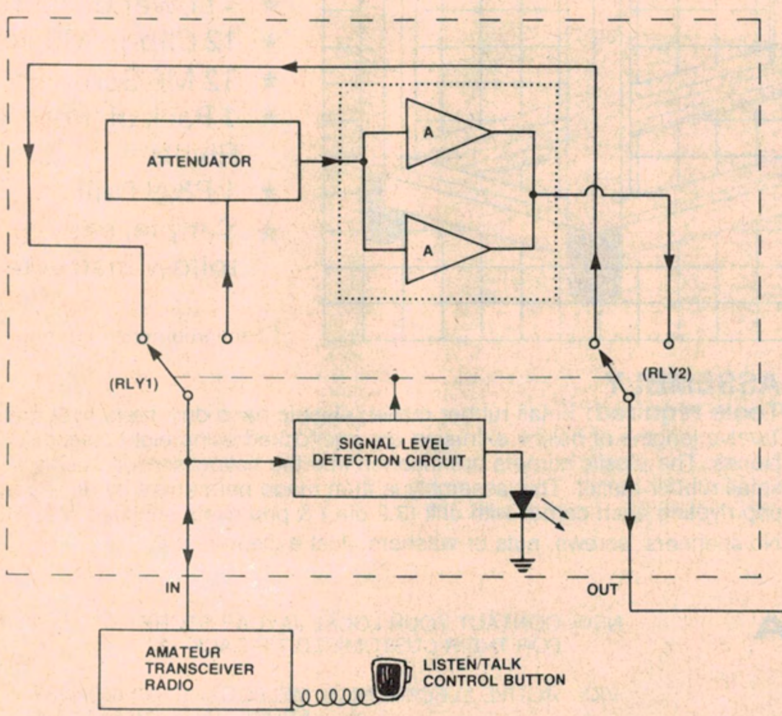


Figure 1. The three basic parts of the amplifier: attenuator, amplifying circuit and signal level detection circuit.

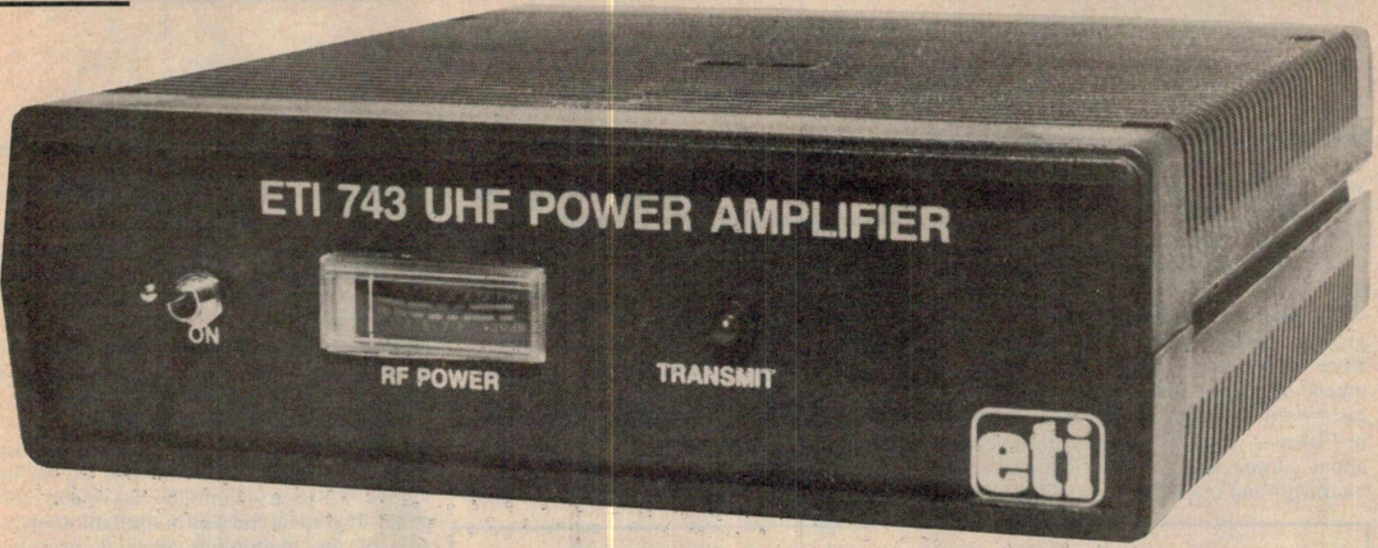
Amplifier circuit principle

The idea of the ETI-743 UHF amplifier is quite simple. As soon as you start transmitting, the amplifier senses the signal and boosts it up to 25 watts! In the absence of a transmitting signal (receiving mode), the amplifying circuit is bypassed, thus allowing the transceiver to directly see the received signal from the antenna.

The ETI-743 amplifier should be used for amateur radio transmissions. Although technically it could be used in UHF CB band operation in that same frequency range, you must check the conditions of your licence to make sure that it does not exceed the power level stipulated.

The amplifier can be divided roughly into three parts: attenuator, amplifying circuit and signal level detection circuit (see Figure 1). The signal level detection circuit senses the strength of the transceiver output signal. Depending on how strong the signal is the circuit will turn the LED and the relays (RLY1, RLY2) on or off. As soon as the ETI-743 circuit is turned on, a signal path is set up, linking the antenna directly to the output of your transceiver. This allows you to listen to the air as usual.

Pushing the "talk" button on your transceiver radio will activate the signal level detection circuit. As a result both relays and



the transmitting LED will be turned on to indicate that amplification is activated. The output signal from the transceiver will be connected to the attenuator by RLY1. The output of the attenuator feeds IC1 and IC2, the hybrids, and output of these hybrids is fed to the antenna by RLY2.

These Motorola MHW710-2 hybrid rf amplifiers (IC1 and IC2) are connected in parallel using four matching transmission lines. These minimize the reflection of signal due to impedance mismatching. Each amplifier by itself can deliver a maximum of 12.5 watts. Two combined will give an exciting 25 watts output. These amplifiers are capable of operating over a frequency range from 440 MHz to 470 MHz.

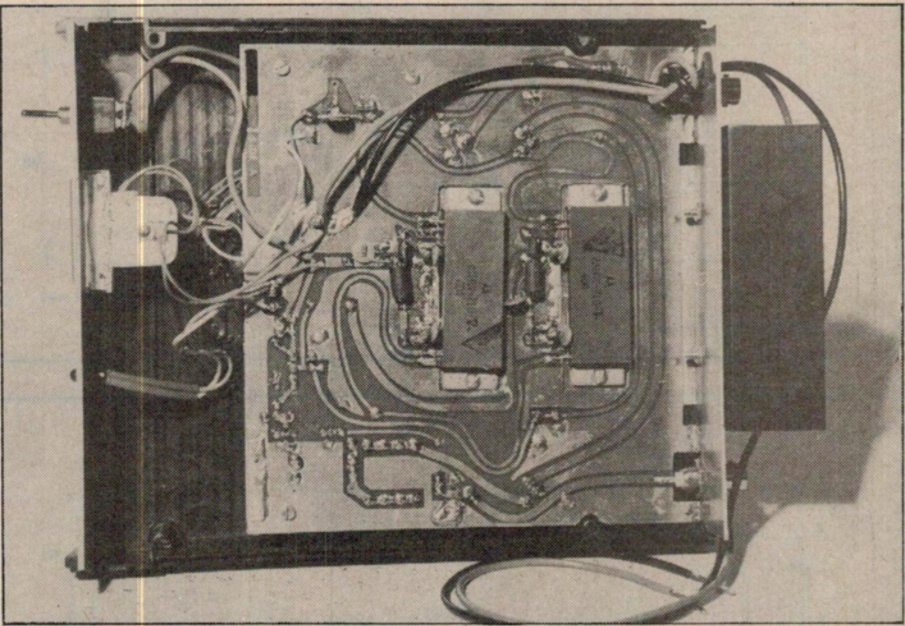
At first sight, the attenuator network looks rather redundant, however it is important. It attenuates the transmitting signal to a power level that won't saturate the hybrid amplifiers. A 300 mW signal is required by the two rf hybrid amplifiers (each takes 150 mW), to obtain maximum output power.

Most amateur transceiver radios are 5 W output. If yours isn't you must carefully choose the right attenuation to suit your particular transceiver. The selected resistance values shown in the Parts List for R1 to R7 are suitable for 4 to 5 W transceiver radios only. If you happen to be one of the unlucky few who have a 1 or 2 W output transceiver radio, some fiddling of the resistance values is unavoidable (see "attenuator" box).

Construction

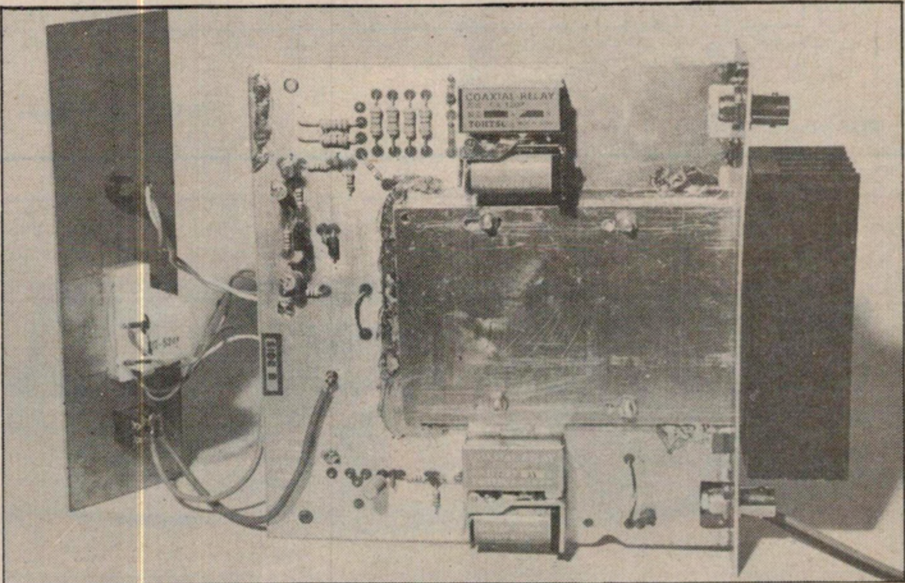
The construction work involved in this project is more mechanical than electrical. Instead of the usual method of assembling the board first and somehow mounting it later, you will have to sort out mounting problems first.

You must first make the cut-outs on the main pc board as shown on the pc board artwork. Cut the front and rear panels from a single sided pc board. Rectangular holes and slots have to be cut out in the front and ▶



Side A ▲

▼ Side B



rear panel as well as the main board. This can be done by first drilling a hole somewhere inside the area you want to cut out, inserting a saw blade through the hole and cutting out the area.

Next drill and cut all the holes on the main board and the panels. In order to reduce the ground plane impedance, the grounded tracks on both sides of the board have to be joined together electrically by means of copper foil. Three pieces of foil need to be soldered in the positions shown in Figure 2. The 28G copper foil is cut to about 23 mm wide, 12 mm long, soldered on the ground track, bent round the edge of the board and soldered onto the other side of the board. Now get a bigger piece of copper foil (about 108 x 81 mm) of 24G and solder it onto side B of the pc board as shown in Figure 2, to cover the rectangular holes. I know how anxious you are to solder the components on board but wait a little longer, you will find it worth the time.

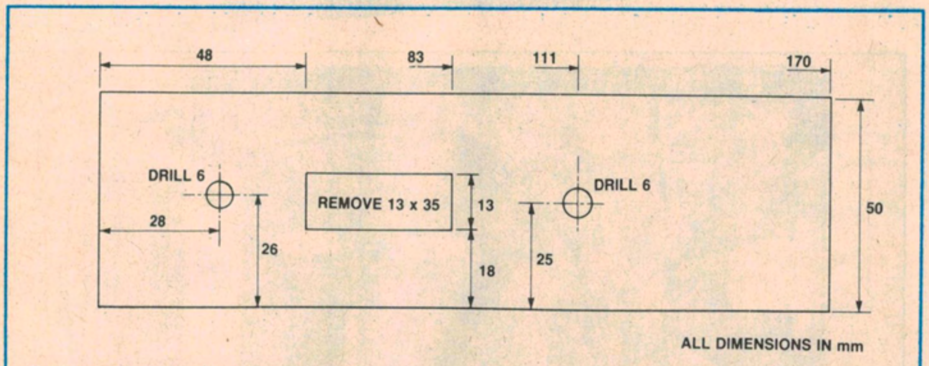
The next thing you have to do is to mount the main pc board into the case. If you have the right plastic case, there will be four plastic mounting studs standing out on the floor. Put four 12 mm spacers on the mounting studs. Land the main pc board with side A facing up gently on the spacers without knocking them down. If the mounting holes on the pc board were drilled correctly, they should align with the spacers. Fasten the board with 20 mm long, ⅛" screws and insert the rear panel. The kinky edge of the main board should now touch the rear panel to form a right angle. With the copper side of the rear panel facing the kinky edge, the main board is soldered onto the rear panel to make this right angle structure rigid and sitting comfortably in the case.

The trickiest part is the mounting of the heatsink and the two hybrid amplifiers. An aluminium angle about the size shown in Figure 3a is inserted into the slot on the rear panel. It goes all the way in until the shorter arm of the aluminium angle is pressing against the rear panel. The longer arm of the aluminium should be forced to press tightly against the large copper foil you just soldered on the main board. You should put something between the longer arm of the aluminium and the floor of the case to provide the support for the aluminium while you drill it.

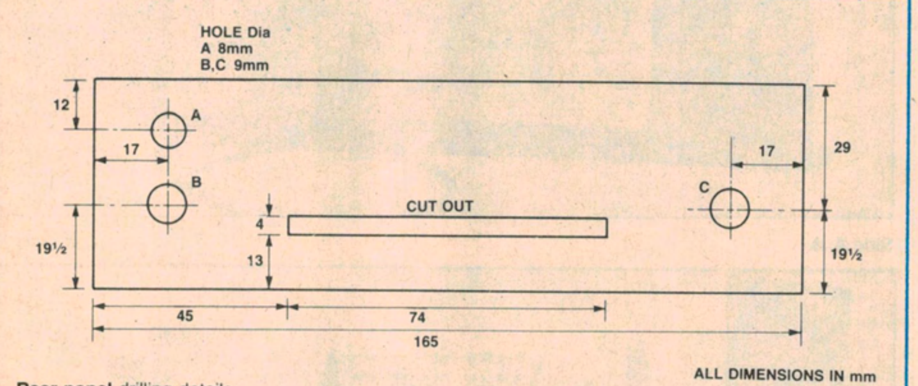
Now put the two hybrid amplifiers into the rectangular holes on the main board, and align the pins of the amplifiers with their corresponding tracks on side A of the board. Carefully mark out the mounting holes for the amplifiers on the copper foil using a sharp needle. Remove the hybrids and drill the four holes on the copper foil according to your marking. The holes should go right through the aluminium as well. You should mount the hybrid amplifiers onto the copper foil using a heat transfer compound on the bottom sides of the amplifiers. Screw the amplifiers down firmly and solder their pins onto the pc board.

Take a heatsink with dimensions as shown in Figure 3b. Drill two holes in it (for ⅛" screws) about 50 mm apart between two vanes, at about half its height. The heatsink is then placed against the shorter arm of the aluminium angle. On the surface of the shorter aluminium arm mark two corresponding holes and drill them right through to the rear panel. Evenly spread the heat transfer (silicon) compound on the aluminium surface. This sandwich structure (heatsink-aluminium-rear panel) is then fixed by using two ¼" screws. Holes B and C as shown in rear panel drilling details are for mounting two BNC connectors on the rear panel. When you do so make sure their pins are lying flat on the corresponding tracks on the main board; they are soldered directly onto the tracks. Make sure the connectors are firmly tightened.

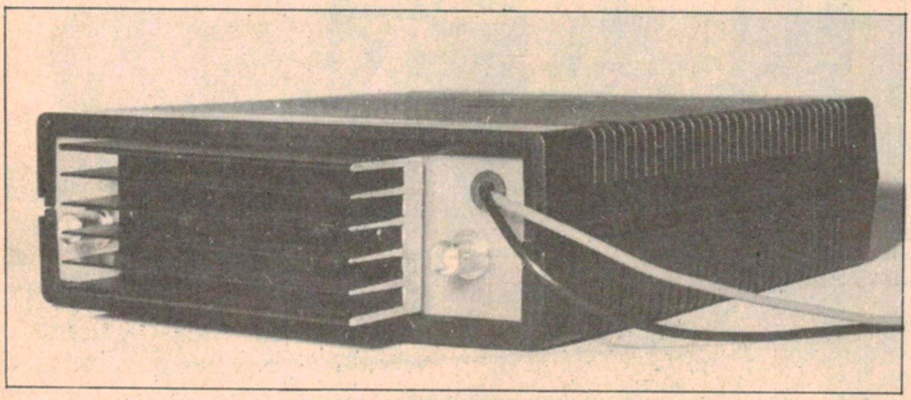
The rear panel, heatsink, main board and the aluminium should now form one single rigid structure. Remove this structure from the case and you can start putting components on the main board. You will find some of them are sitting on side A of the ▶



Front panel drilling details.



Rear panel drilling details.



HOW IT WORKS — ETI-743

The rf signal at the BNC input (see Figure 2) is sensed by capacitor C1, and rectified by diodes D1 and D2 before driving the base of transistor Q1. In the receiving mode, the signal from the antenna is not strong enough to turn on Q1. Under this condition, the LED is off, relays are not energized and the amplifying circuit is idle.

As soon as you start transmitting, the much stronger signal from your transceiver radio output will turn on Q1, thus short circuiting capacitor C3, and forcing R14 and R10 to form a potential divider generating roughly 5.3 V to the base of transistor Q2. This voltage is enough to saturate Q2 (that is, turn it on). The emitter junction of the turned-on Q2 starts to conduct like a forward biased diode and this diode, in shunt with the D3 and R14, effectively brings the 5.3 V back to about 11.3 V. The base current is then limited by R10 to around 11.3 mA.

Both relays RLY1, RLY2 and the LED are connected in parallel. The saturated Q2 will give rise to about 12 V across all three turning them on. Current through the LED is limited to about 12 mA by R11; current through the relays is limited by their resistances. Diode D4 and capacitor C8 are there to protect the transistor Q2 from the damaging inductive effect of the relays' coils during switching.

The amplifying circuit consists of two hybrid amplifiers (IC1 and IC2) each of which has a gain of 19.2 dB. A 150 mW signal injected into one will give an output power of $0.15 \times 10^{1.92} = 12.5$ watts. Two in parallel gives 25 watts but requires a 300 mW input signal.

Connecting both amplifiers together is not an easy job at all. Impedance matching has to be allowed for or signal reflection may occur. Most transceivers have an output impedance of 50 ohms. The input impedance of each hybrid amplifier is also 50 ohms. Connecting two hybrids in parallel obviously won't give 50 ohms anymore. The idea is to connect each amplifier input with a transmission line before they join together. The characteristic impedance of both transmission lines is 75 ohms and they are a quarter wavelength long.

The impedance looking into each amplifier with a quarter wavelength long transmission line connected becomes 112 ohms. Since there are two in parallel, the input impedance looking into the whole amplifying circuit becomes 112/2 = 56 ohms, which is pretty well matched to your 50 ohm radio. A similar arrangement connects the amplifiers' outputs together to match your 50 ohm antenna. These four transmission lines are printed as normal copper tracks on a pc board with their lengths carefully calculated.

As you may have noticed from the circuit diagram or the mask of the layout, diode D5 connects to the ground through a short piece of copper track. It acts like a little antenna picking up the rf signal from the circuit, rectified by D5. The output drives the M1 meter. Hence the meter provides the indication of the strength of the rf signal.

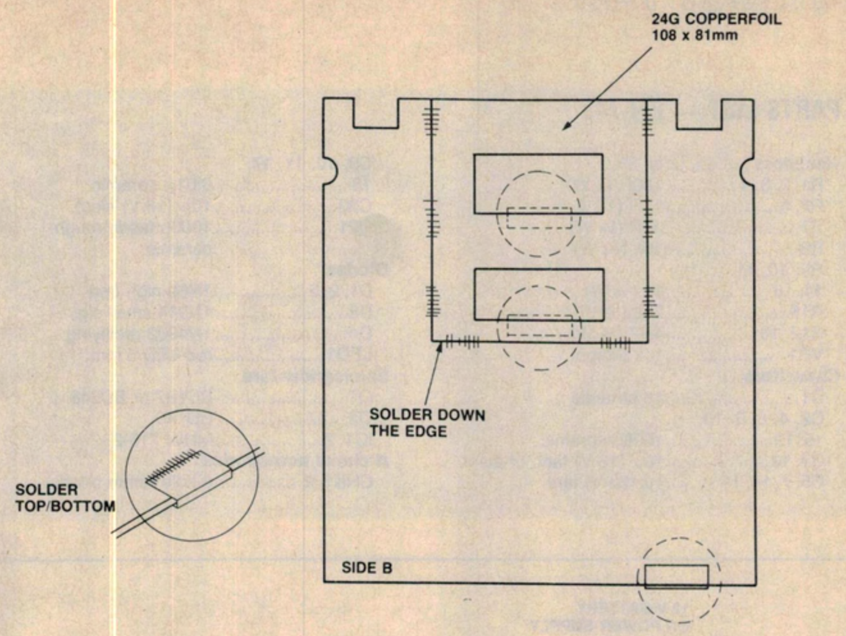


Figure 2. Copper foil soldering positions. Three pieces of foil should be soldered into position. The larger square piece of foil is soldered on to cover two of the small pieces.

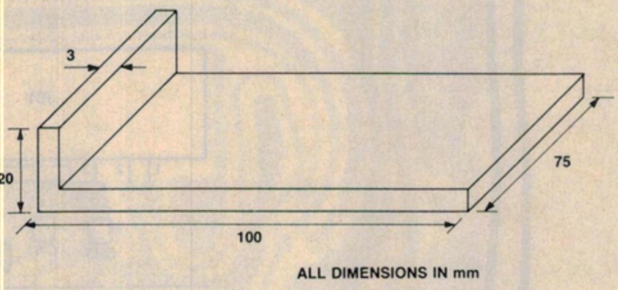


Figure 3a. Dimensions of aluminium angle.

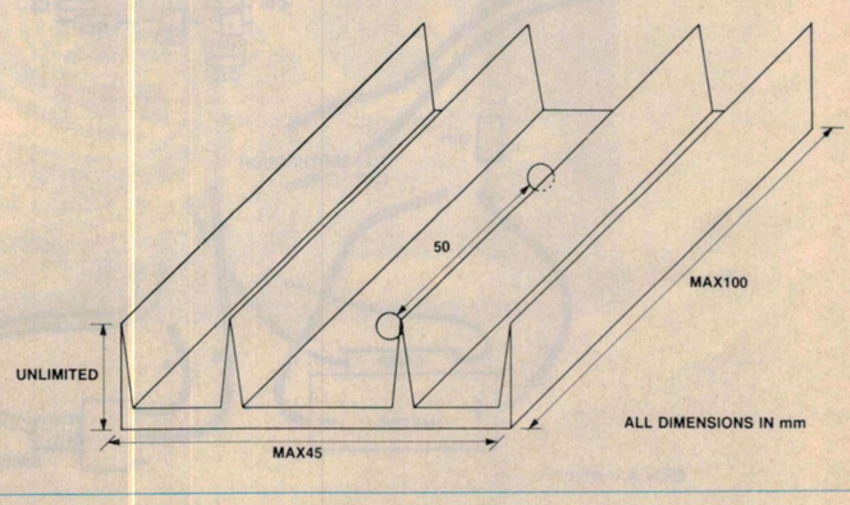


Figure 3b. Heatsink dimensions and drilling details.

PARTS LIST — ETI-743

Resistors ....all 5%
R1, 2, 3, 4 ....180R (1 W)
R5, 6......................12R (1 W)
R7.........................39R (¼ W)
R8.........................10k (¼ W)
R9, 10, 11,
14, 16 ....1k (¼ W)
R15........................2k2 (¼ W)
R12, 13..................4R7 (¼ W)
VR1 ....10k trimpot

Capacitors
C1..........................1p ceramic
C2, 4, 6, 8, 13,
15, 19 ....1000p ceramic
C3, 12....................10µ (16 V) tant. or elect.
C5, 7, 14, 16..........1µ (35 V) tant.
C9, 10, 11, 17,
18 ....0.01µ ceramic
C20........................10µ (16 V) elect.
C21........................1000p feedthrough ceramic

Diodes
D1, 2, 5 ....1N60 high freq.
D3..........................1N914 small sig.
D4..........................1N4002 rectifying
LED1 ....red LED 5 mm

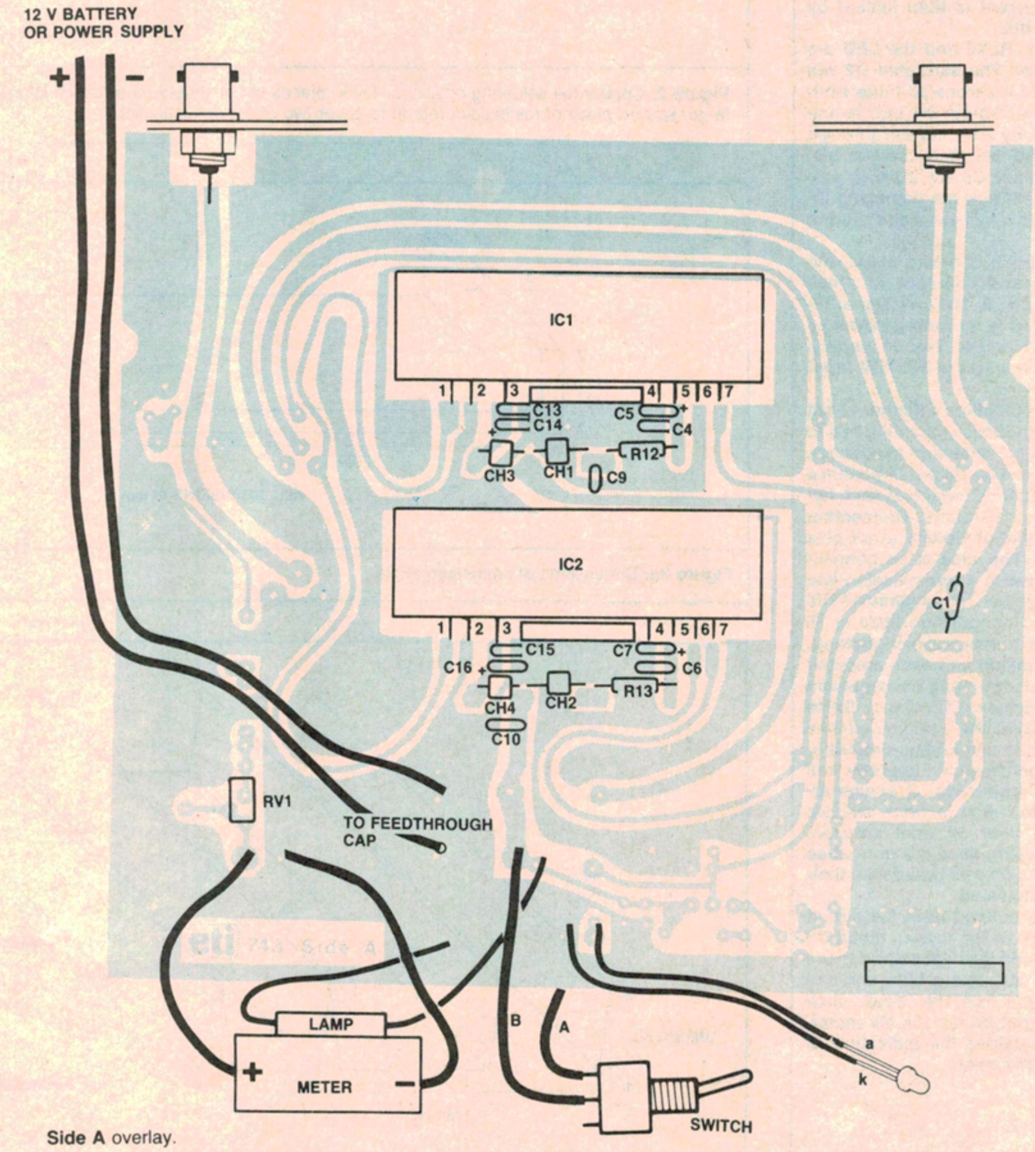
Semiconductors
Q1 ....BC107 or BC548
Q2 ....BD140
IC1, 2......................MHW 710-2

rf choke accessories
CHK1, 2..................6-hole ferrite bead
CHK3, 4..................single hole ferrite bead

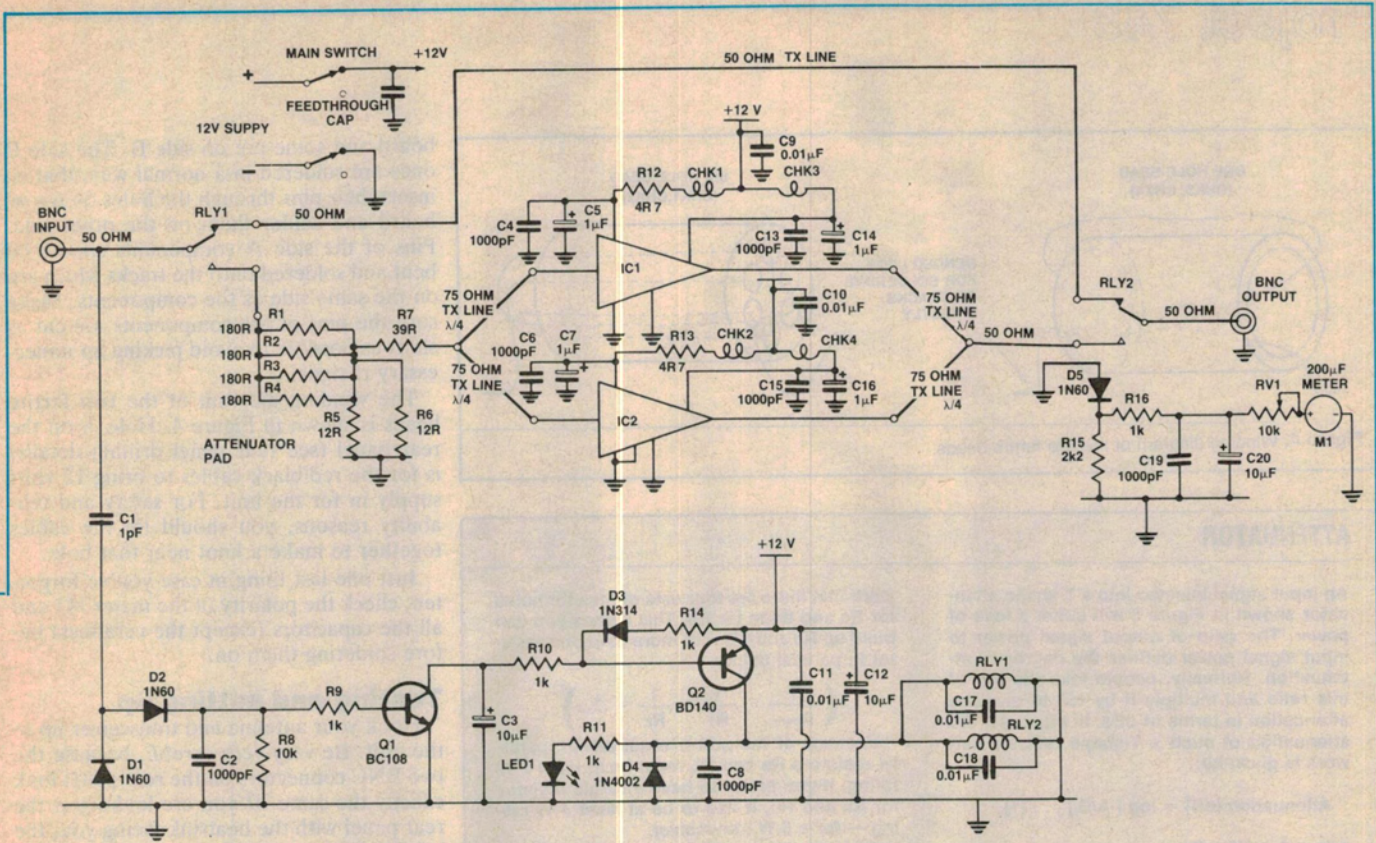
Miscellaneous
SW1 ....DPDT toggle switch
BNC1, 2..................BNC connectors
M1 ....200 µA meter
RLY1, 2 ....coaxial relays

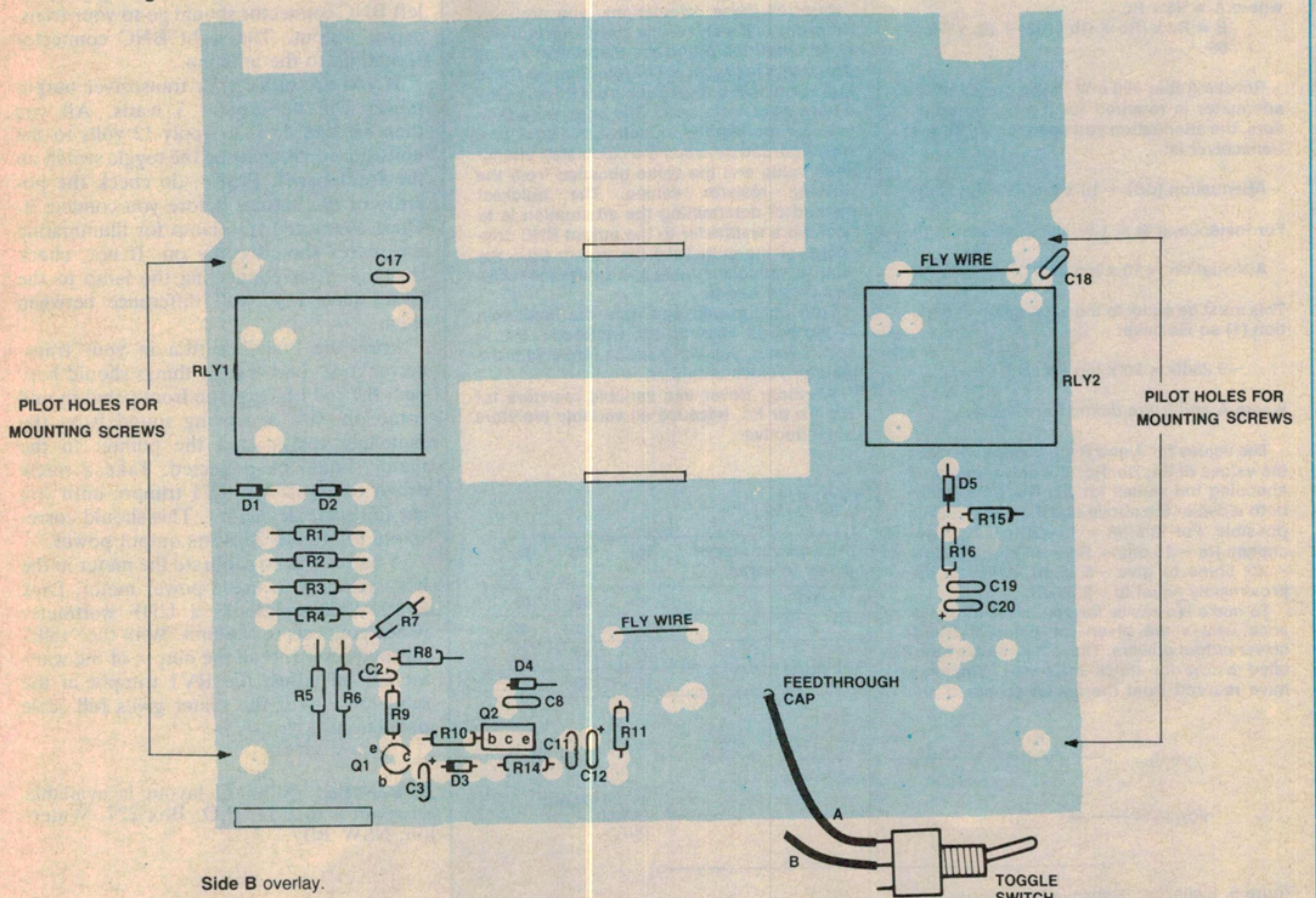
One 24G copper foil (108 x 81 mm); one 28G copper foil (23 x 36 mm); LED holder; four spacers; 100 mm heatsink for IC1, IC2; a right angle aluminium section; one plastic case (210 x 175 x 55 mm); front and rear panels; one double sided pc board; 500 mm red/black wire, a short length of 25BNS insulated wire for making the rf chokes; 10 nuts and screws (1/8″) for mounting the hybrid amplifiers.

Price estimate: from $129



Side A overlay.





Side B overlay.

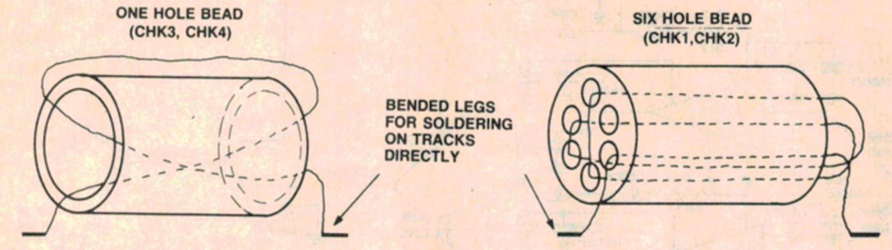


Figure 4. Winding diagram of the two ferrite beads.

board and some are on side B. The side B ones are soldered in a normal way, that is, insert their pins through the holes on the pc board and solder them on the other side. Pins of the side A components should be bent and soldered onto the tracks which are on the same side as the components. Make sure the pins of the components are cut as short as possible to avoid picking up unnecessary rf signal.

The winding diagram of the two ferrite beads is shown in Figure 4. Hole A on the rear panel (see rear panel drilling details) is for the red/black cables to bring 12 volts supply in for the unit. For safety and reliability reasons, you should tie the cables together to make a knot near that hole.

Just one last thing in case you've forgotten, check the polarity of the meter M1 and all the capacitors (except the ceramics) before soldering them on.

Testing and setting up

Hook your antenna and transceiver up to the unit. Be very very careful, because the two BNC connectors on the rear panel look exactly the same. If you are looking at the rear panel with the heatsink facing you, the left BNC connector should go to your transceiver output. The right BNC connector should go to the antenna.

If you are lucky your transceiver output power will be around 5 watts. All you then have to do is to apply 12 volts to the unit and turn it on using the toggle switch on the front panel. Please, do check the polarity of the battery before you connect it. Once connected, the lamp for illuminating the meter should come on. If not, check that the wires connecting the lamp to the board have a 12 volt difference between them.

Press the "talk" button in your transceiver radio and several things should happen: the red LED on the front panel should come on with a clicking sound from the switching relays, and the pointer in the meter should be deflected. Take a screw driver to adjust the RV1 trimpot until you get full scale deflection. This should correspond to around 25 watts output power.

A better way to calibrate the meter in the front panel is to use a power meter. Dick Smith Electronics has a UHF wattmeter which connects to the unit. With the "talk" button pressed, read the output of the wattmeter and adjust the RV1 trimpot at the same time until the meter gives full scale deflection.

Artwork: pc board layout is available on request to ETI, P.O. Box 227, Waterloo, NSW 2017.

ATTENUATOR

An input signal injected into a T-shape attenuator shown in Figure 5 will suffer a loss of power. The ratio of output signal power to input signal power defines the degree of attenuation. Normally, people take the log of this ratio and multiply it by ten to give the attenuation in terms of dBs. In our case, the attenuation of such a T-shape resistor network is given by:

Attenuation (dB) = log [A/B] . . . (1)

where A = 56 x Rc
B = Ra x (Rc + Rb + 56) + Rc x (Rb + 56).

Recalling that 300 mW in the output of the attenuator is required for the hybrid amplifiers, the attenuation you need for an 'M' watt transceiver is:

Attenuation (dB) = 10 x log (0.3/M) . . . (2)

For instance, if M = 1 W, using equation (2):

Attenuation = 10 x log (0.3/1) = −5.23 dB

This must be equal to the expression in equation (1) so we have:

−5.23dB = 20 x log [A / B]

where A and B are defined previously.

The values for A and B are dependent upon the values of Ra, Rb, Rc. It is only a matter of choosing the values for Ra, Rb, Rc to make both sides of the above equation as equal as possible. For this 'M = 1' watt case, I have chosen Ra = 15 ohms, Rb = 18 ohms and Rc = 82 ohms to give −5.25 dB, which is approximately equal to −5.23 dB.

To make life easier for you, a set of resistance values are given for different transceiver output powers. These figures are tabulated below for quick reference. You may have realized from the actual pc board artwork that there are four sets of resistor holes for Ra and three for Rb. This means you can build up Ra and Rb with more than one resistor in parallel using:

$$\left(\frac{1}{R_{com}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots\right)$$

Because of the power requirement, parallel resistors Ra and Rb must be at least 1 W rating. If you prefer to have a single resistor for Ra and Rb, it has to be at least 4 W rating — for a 5 W transceiver.

After all these calculations, you probably think this is the end of the story. Unfortunately, it is not! We found the theoretical values don't work in practice. The numbers you have just calculated or borrowed from the table assumed pure resistance. The ones we use in practice are slightly inductive. A factor of 2 was recorded between the calculated attenuation value and the value obtained from the working resistor values. The quickest method of determining the attenuation is to hook up a wattmeter to the output BNC connector of the unit. Take the values from the table (or calculate them) and solder the resistors on the board.

Turn on the unit and note the indication of the power level on the wattmeter. If it is not 25 watts, you will have to fiddle with the resistor values until it is.

Warning: Never use variable resistors for Ra, Rb or Rc, because all variable resistors are inductive.

TABLE 1

Transceiver output power in watts	Ra	Rb	Rc
1	15	18	82
2	110	22	47
3	27	27	33
7	33	33	22

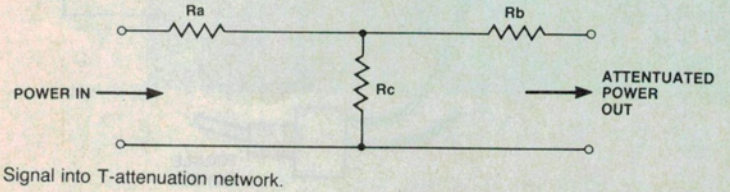


Figure 5. Signal into T-attenuation network.