70W booster amplifier for 28 and 52 MHz

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NOW THAT OLD SOL is at the peak of his/her/its 11-year activity cycle, interest in the DX opportunities available on the amateur 'six' and 'ten' metre bands (28 MHz and 52 MHz respectively) has also 'peaked'. Most of the popular commercial transceivers available for six metre operation have an output around 10-15 watts, PEP – SSB being the popular mode on this band. Homebrew transmitters for this band, too, generally put out about 10-20 watts as it is relatively easy to generate this sort of power using components widely available. Many designs have been presented in the wide-circulation amateur publications like QST, 73 and Ham Radio.

Whenever the six metre band 'opens', especially to one of the rarer areas, one can observe about four layers in the ensuing 'dog piles' of calling stations. The first – and strongest – stations in the pile are those running high power linears, known as "the big boys" for most of them run 300-400 watts PEP output (the legal limit). The next layer consists of a large number of operators running around 50-60 watts output, generally from a transverter driven by a HF transceiver. They are known as "the transverter brigade". The third layer consists of those operators running 'barefoot' transceivers, either homebrew or commercial systems, with around 10-20 watts output. They are known as "the barefoot boys". The bottom of the pile is occupied by stations running low power commercial transceivers (such as the popular Icom IC501) or homebrew rigs – known as "the QRP brigade". This classification is remarkably reminiscent of class stratification in Victorian England . . .

On six metres many of the anomalous propagation modes that provide the DX opportunities so many VHF enthusiasts delight in exploiting are often-times marginal and results depend a lot on the amount of power you run. And if you want to explore meteor scatter (popular during the previous solar minima), a power output of at least 50-60 watts minimum is required for reasonable results.

This booster amplifier will move you up one rung in the dog pile layers.

Similarly, on the ten metre amateur band, one can have a lot of fun with a converted CB rig. They have an output of 10-12 watts PEP, and can be 'coaxed' a little further, but not a significant amount. This booster amp should put you into much the same power bracket as most of the all-band transceivers.

DX542CF RF POWER TRANSISTOR – TYPICAL CHARACTERISTICS

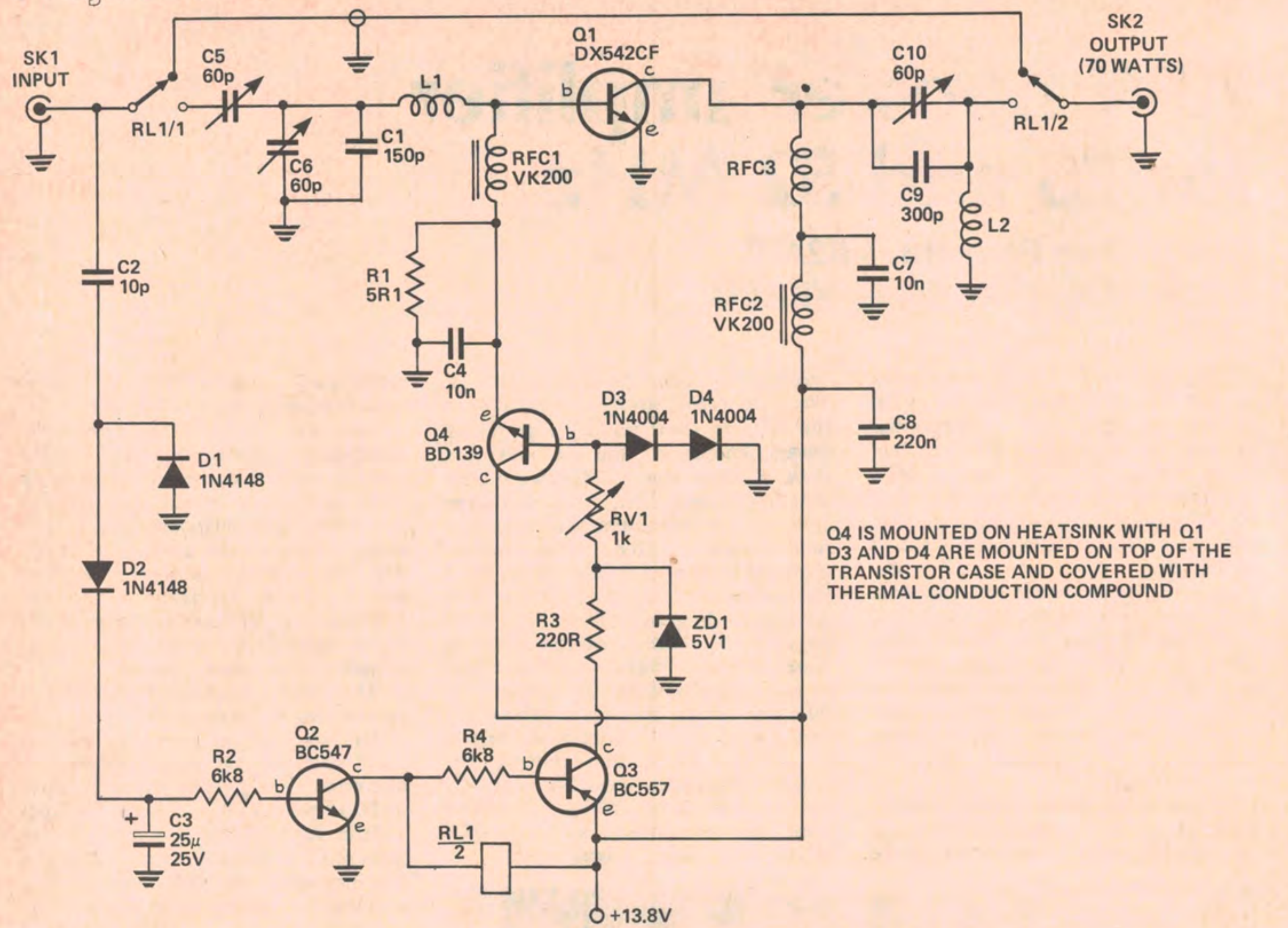
F (MHz)	G (dB)	Input Z (series)	Output Z (parallel)	IMD (dB)
30	13	R1.47 - j0.3	1170pF & 1.2 ohms	>30
50	9.3	R1.36 - j0.3	937pF & 1.56 ohms	>30

Circuit features

The design is very straightforward, centred on a Philips RF power transistor – the DX542CF, a fairly recent release. It has been carefully chosen for optimum linearity and performance in the 30-50 MHz region.

Automatic, signal-sensed antenna changeover is provided and the bias network has been arranged to turn off when the amplifier is not in-circuit, thus the booster does not draw current during receive – an important consideration for mobile or portable operation.

Apart from the RF power transistor, no specialised components have been used. When we published the series of ETI-715/716 VHF power amplifiers about two years ago, special mica compression trimmers were specified – expensive, and now difficult to get. This design uses inexpensive, commonly-available Philips film trimmers. The amplifier may be mounted onto a variety of available heatsinks, a special single-sided heatsink is not necessary. ▶



HOW IT WORKS – ETI 726

The amplifier employs a single RF power transistor operated in Class B. The bias network and antenna changeover are operated by a circuit which senses the presence of input signal.

Taking the amplifier itself: the input is via SK1 and the antenna changeover is operated as soon as a very small amount of input signal from the transceiver is present. With RL1/1 operated, input is applied to the base of Q1 via an impedance matching network consisting of C5, C6 and C1 with L1. Bias is applied to the base of Q1 via RFC1. Output from the collector of Q1 is passed to the output socket, SK2, via another impedance matching network consisting of C9, C10 and L2, thence via RL1/2. Collector supply for Q1 is shunt fed via RFC2 and RFC3. The RF power transistor, Q1, has a power gain of around 8.5 - 9.5 dB so an input of about 10 W PEP will result in an output of 70 W PEP or more.

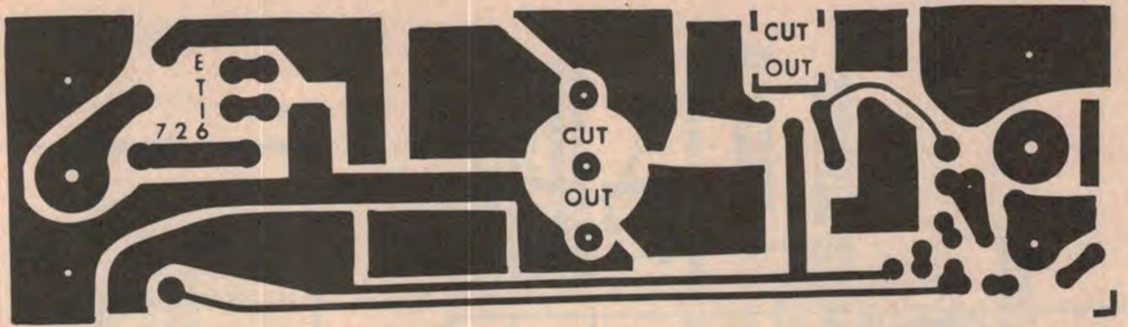
The input signal-operated bias and antenna changeover circuit operates as follows: a small amount of input signal is bled off by C2 and is rectified by a voltage doubler consisting of D1 and D2. This will charge C3, applying forward bias to the base of Q2 via R2. When Q2 conducts, RL1 will operate, diverting the transmit signal from the transceiver via the amplifier. At the same time, base-emitter current will flow in Q3, via R4, turning Q3 on. It will draw collector current via ZD1 and R3. Thus, Q4 will be forward-biased from ZD1 via RV1, diodes D3 and D4 clamping the voltage on the base to about 1.2 - 1.4 volts. The base of Q1 will be forward-biased via the emitter of Q4, the base-emitter drop of Q4 allowing only about 0.6 volts to appear on the base of Q1. RF and dc earth-return for the base-emitter of Q1 is provided by R1 and RFC3.

When the input signal disappears, C3 will discharge via R2 and the base-emitter of Q2. When the voltage on the base of Q2 falls below about 0.5 V, about half a second after the input ceases, Q2, along with Q3, Q4 and thus Q1, will turn off and RL1 will release, returning the booster amp to the 'receive' condition.

Construction

A double-sided printed circuit board is used. The underside, in contact with the heatsink, is unetched copper which provides a healthy 'ground plane'. The 'top' side is etched and the components mounted directly between the pads (take a close look at the photograph). There are two cutouts required in the board, one for the RF power transistor, Q1, and one for the bias transistor, Q4. Make sure that each device clears the edges of the cutouts. There should be about 1-2 mm clearance all round.

Two shim straps, each about 3-4 mm wide and about 10 mm long, should be soldered from each emitter pad of Q1 on the top of the pc board to the ground plane underneath. This should be done first thing. Ensure that Q1 still passes through the cutout and does not foul the shim straps. Two other shim straps are required – one adjacent to



the input socket, and one adjacent to the output socket.

Next, mount the three trimmer capacitors. Bend their leads out from the component's case at a right angle. The fixed plates in these Philips trimmers have two connection leads, the fixed plates having only one. You can check this quite simply by examination of the trimmer. The fixed leads of C6 should be soldered to the ground pad (see pc board overlay) while the single moving plate lead of C5 should be soldered to the input pad (connected by coax to RL1 – see the overlay again). This avoids one of the leads of C5 fouling Q4. All the resistors and capacitors can then be mounted – save C2, which is left until after the pc board is assembled to the heatsink. Note that C9 on the 52 MHz model is actually three 100 pF ceramic capacitors in parallel (refer to the pc board overlay). Note also that the resistors are all stood on end. In the 28 MHz model, C7 consists of two 150 pF capacitors in parallel, while C9 is five 100 pF capacitors in parallel.

Now you can mount diodes D1, D2 and ZD1 – watch the polarity of these components. Follow this by mounting the two transistors Q2 and Q3.You can also solder the leads of Q4 to the board at this stage. Prior to soldering, bend a "U" in each lead, fairly close to the body of the transistor. The "U" will be about 1-2 mm across and about 2-3 mm high and on the *plastic* side of the transistor body. Cut each lead at the end of the U and bend a small bit out away from the body – this part solders to the pc board (the shape of each lead should look like an Ω symbol). This bend provides some resilience in the leads to prevent damage to the transistor when it is screwed down to the heatsink later.

Note that diodes D3 and D4 are left until the pc board and Q1 are mounted to the heatsink.

The two ferrite RF chokes, RFC1 and RFC2, consist of a length of 22 gauge tinned copper wire passed through five holes in a Philips six-hole ferrite bead – type 4312-020-31550. These can actually be obtained from a number of suppliers already wound and are known as "VK200" RF chokes. Alternatively, you can buy the beads separately (they are widely available) and wind them yourself.

The input and output coils, L1 and L2 may now be wound and mounted. They are constructed of 18 gauge tinned copper wire. The collector decoupling choke, RFC3, may be wound and mounted next. It is constructed of 20 gauge enamelled copper wire.

The antenna changeover relay, RL1 is the next item to attend to. Whilst holding it above the position it will occupy on the pc board, carefully bend each lead out so that it matches the corresponding pad on the board. Then solder it in place. Take a look at the photograph to check orientation.

At this point in the construction the board may be placed on the heatsink and used as a template to mark the hole drilling positions for the input and output coax sockets. Drill the holes to suit. Then, temporarily secure the board to the heatsink with the coax socket mounting bolts and mark the position of the hole required for the securing bolt for Q4. Also, carefully place the RF power transistor in the pc board cutout – correctly oriented – and mark the position of the two mounting bolt holes it requires. Disassemble the pc board and coax sockets from the heatsink and drill the latter.

Small self-tapping "PK" screws can be used to secure Q1 and Q4 so the heatsink need not be drilled right through. Drill a hole in each marked position using a drill which is the root diameter of suitable PK screws – a 1.5 – 2.0 mm diameter drill should be fine. Alternatively, you can tap the hole to take an appropriate screw, if you have the tools. Then again, you can drill right through and use a bolt, nut and washer. Whatever suits you and is mechanically suitable is fine.

Now, Q4 needs to be insulated from the heatsink as the metal area on the device is connected to the collector which is connected to the positive supply rail. Thus, an insulating washer is required. Smear both sides of the washer with silicone thermal compound (such as Bevaloid GS13 or other proprietry silicone heatsink paste).

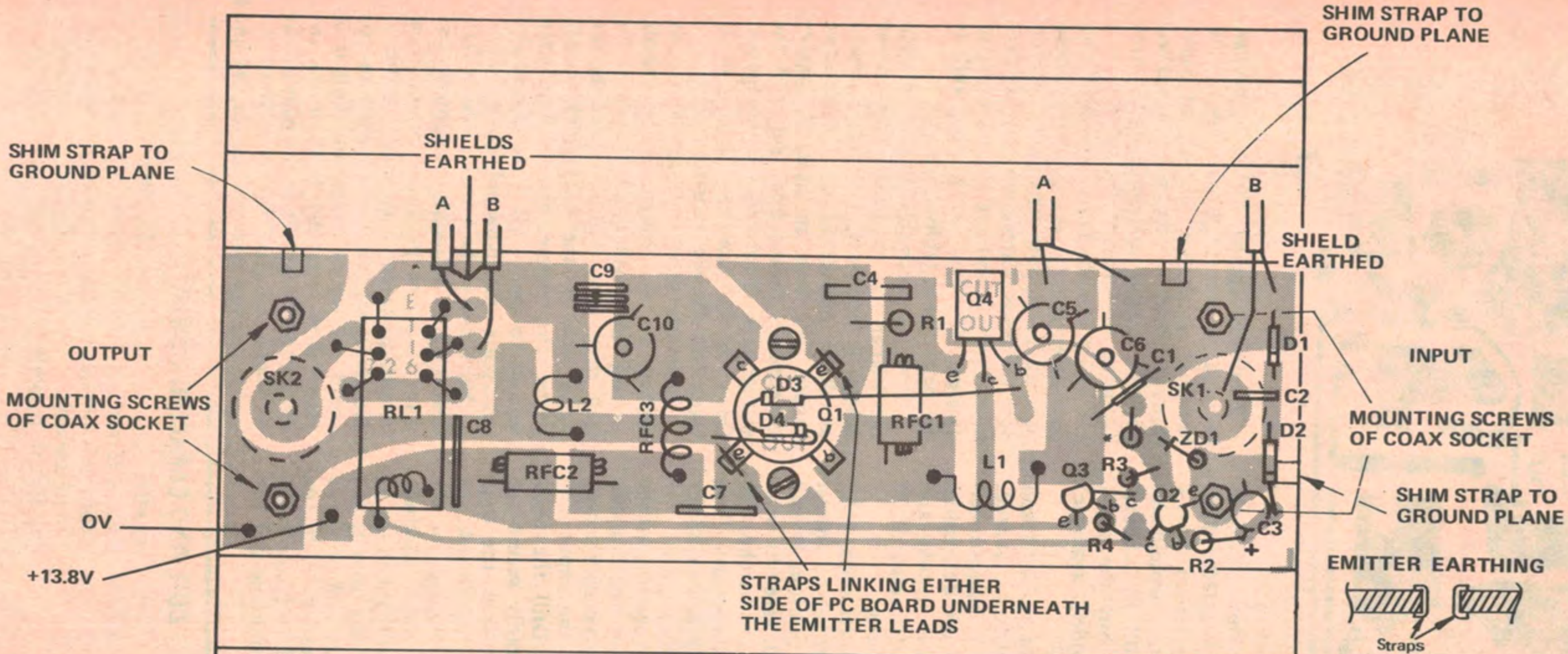
Assemble the pc board and coax sockets to the heatsink once again, placing Q4's insulating washer over the bolt hole first. Tighten the nuts and bolts securing the coax sockets and solder the centre pins of the coax sockets to their pads – make sure you get a good joint. Now bolt down Q4.

Next, smear the bottom side of Q1's header with heatsink compound and place it in the pc board cutout being careful to orient it correctly. Refer to the transistor package diagram and pc board overlay to assist you. Bolt it in place then carefully bend down the leads and solder them to the pads on the pc board, being careful not to strain the leads. The bias network diodes, D3 and ▶

COIL AND CAPACITOR DATA

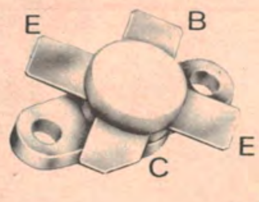
Coil	52 MHz	28 MHz
Input, L1	2 turns, 6 mm i.d.	3 turns, 6 mm i.d.
Output, L2	1 turn, 9.5 mm i.d.	3 turns, 9.5 mm i.d.
C1	150 pF ceramic	2 x 150 pF ceramic
C9	3 x 100 pF ceramic	5 x 100 pF ceramic
RFC3	7 turns, 6 mm i.d.	9 turns, 6 mm i.d.

Wire gauge: Coils L1 and L2 use 18 gauge B & S tinned copper wire; RFC3 uses 20 gauge enamelled copper wire.



This is effected by folding shim straps over the edge of the pc board. Two to four mil shim stock serves very well. Note the three other shim straps.

The DX542CF package and lead connections..



SK1 and SK2 mounted on heatsink with centre pin soldered onto pc board. Q1 and Q4 are mounted onto heatsink through cutouts in pc board. RL1 has pins bent to allow soldering to the pc board. All resistors are stood on end. The base lead of Q2 must be slightly bent to fit correctly. *RV1 used to set bias and can be replaced with a fixed resistor (shown).

PARTS LIST - ETI 726

Resistors all ½W, 5%
- R1 . . . . 5R1
- R2 . . . . 6k8
- R3 . . . . 220R
- R4 . . . . 6k8
- RV1 . . . . 1k (vert mounting min trim pot (can be replaced with fixed resistor)

Capacitors
- C1. . . . . see coil table
- C2. . . . . 10p disc ceramic
- C3. . . . . 25μ 25V electro
- C4. . . . . 10n disc ceramic
- C5, C6 . . . . . 60p trimmer - see text
- C7. . . . . 10n disc ceramic
- C8. . . . . 220n disc ceramic
- C9. . . . . see coil table
- C10. . . . . 60p trimmer - see text

Semiconductors
- D1, D2 . . . . . IN914, IN4148, etc.
- D3, D4 . . . . . IN4004
- ZD1. . . . . 5V1, 400 mW zener diode
- Q1 . . . . DX542CF Philips power transistor - see text
- Q2 . . . . BC547
- Q3 . . . . BC557
- Q4 . . . . BD139

Miscellaneous
- RFC1, RFC2. . . . . . 6 hole ferrite bead with wire passed through 5 times, Philips VK200 see text
- RFC3. . . . . . see coil table
- L1, L2 . . . . . see coil table
- RL1. . . . . 12 volt pcb mounting relay
- SK1, SK2 . . . SO239 coax sockets

ETI 726 pc board, thermal conduction compound, minifin heatsink (see text), miniature 50 Ω coax, tinned copper wire.

D4 can now be mounted. Place the diodes parallel to one another so that you can twist the anode lead of one diode together with the cathode lead of the other, and then solder them together. Smear the top of Q1 and the two diodes with silicone heatsink compound and put the two diodes on top of Q1. The spare anode lead (from what is now D3) goes to the base lead of Q4, over the top of RFC1 (refer to the pc board overlay). The remaining lead is bent back so that it may be soldered to the emitter (ground) pad adjacent to the grounded end of C7 (refer to the overlay again).

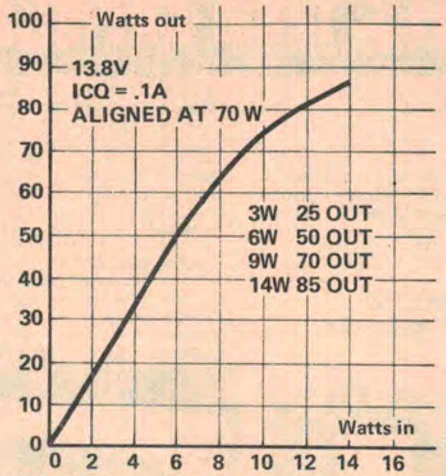
Last of all, solder C2 in place and add the two coax leads, A and B. Use RG174 3 mm diameter coax for these leads. Take care not to melt the insulation of the cables causing a possible short to the shield braid. These cables do not have to be any specific length – just allow enough to reach without the cables being crowded down on the pc board. The supply connections can then be made. This booster may draw 10 A on peaks, so use appropriately rated leads – 23/0076 is a suggested minimum. These leads should be colour-coded to avoid reverse connection, otherwise connect a power diode in reverse across the supply rail as 'idiot' protection.

At this stage, check *everything*. Having satisfied yourself that all is in order, you are ready for test.

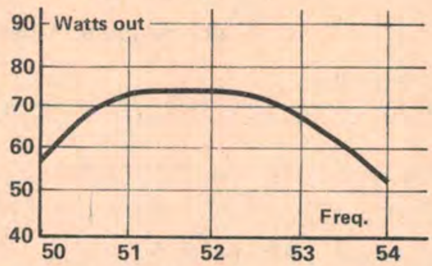
Powering up

You will need a 50 ohm, 50 or 100 watt dummy load, an SWR/power meter, a dc power supply that will deliver 12-14 volts at 10 amps and a 1½ V battery with clip leads attached. A low resistance ammeter to read 10 amps should be connected in series with the dc power supply.

First, connect the SWR/power meter and dummy load to the booster amp's output. No drive should be applied until much later. Connect the dc power supply and check to see that the amplifier draws no current. Taking your 1½ V battery, connect the *negative* terminal to a ground point and then the *positive* terminal to the junction of D1, D2 and C2 – this pad is immediately in front of the input coax socket centre terminal pad. The relay, RL1, should operate and the amplifier should draw around 200-300 mA of current if all is well. Now, lift the end of RFC2 that connects to the power supply rail on the pc board and connect a 0-100 mA meter in series (disconnect the dc power supply first!). With the power supply connected and the 1½ V battery reapplied to the junction of D1, D2 and C2, adjust the trimpot RV1 so that the collector current of Q1, as indicated on the milliameter you just inserted, is 100 mA. Having done that, remove the milliameter, restore RFC2 to its rightful position and you can move on to tune-up.

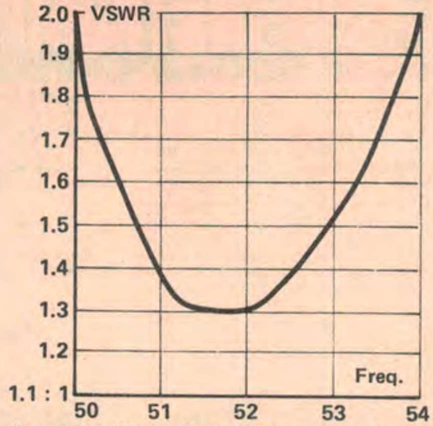


Output versus input power. This applies when the linear is aligned at 70 W out. With 3 W in, the amp can be aligned to give 32 W out.



Bandwidth with the unit aligned at 52 MHz

> **Heatsinks**
>
> The peak dissipation of the RF power transistor is about 50 W, about 20 W average for SSB operation during transmit periods. A heatsink rated between 1°C/watt and 1.5°C/watt should be used to give adequate heat dissipation. The one used on the prototype shown in the picture is a 147 mm length of "Minifin". In fact, the pc board has been designed to drop into this particular heatsink. There are several alternatives. A 152 mm length of Redpoint Q-type or L-type should be suitable. Dick Smith has a 225 mm length of single-sided heatsink that should be more than adequate – it's a little big but is OK if space is not a problem. The pc board would need to be mounted on the flat side.
>
> Whatever heatsink you select you will need a space between the inner fins of at least 33 mm on the side the coax sockets mount and 40 mm on the side the pc board is mounted.



Input VSWR with the linear aligned at 52 MHz and 10 W input.

If you have, or can obtain, another in-line power meter, it would be a wise idea to connect it between your transceiver and the booster amp's input. First adjust your transceiver (into a dummy load) to give an output of 3-4 watts on carrier, or apply a single tone to the mic input and adjust the level to provide a similar power output.

With the transceiver and booster amplifier all connected up, apply drive and tune the trimmers C5, C6 and C10 for maximum power output. If all goes well at this stage, increase the drive to the 10 W level (or peak output of the transceiver, providing it's no greater than 15 W) and peak all the trimmers for maximum output. Check the input SWR.

That's the simplest tune-up method. By far the best method is to use a two-tone test generator and a spectrum analyser – but not every shack has these items!

Now you can give the amp an on-air test.

Performance

Performance graphs for one prototype on 52 MHz are reproduced here. Output linearity and overall gain is dependent on the level at which the unit is aligned. If aligned at 10 W drive you'll get around 75 W output, but at 3 W drive you'll get about 30 W output. Intermod distortion on prototypes has been measured at better than 30 dB down on PEP output (two-tone). On 28 MHz the DX542CF has more gain than at 50 MHz so you'll get somewhat higher output for less drive.

Bandwidth of the unit, when aligned at one frequency, is flat within 1 dB over more than 2 MHz for power output, input VSWR being less than 1.5:1 over the same range.

This amplifier will provide more than adequate drive to a subsequent high power linear amplifier designed to deliver the legal limit of 400 W PEP output. ●