A CB transverter for the 80-metre amateur band

Looking for an inexpensive way to get on the amateur bands? Do you have a 40-channel AM/SSB CB radio lying around? If so, you can build this transverter to convert the CB to the popular 80-metre (3.5MHz) amateur band.

PART 1 – By LEON WILLIAMS, VK2DOB

Many prospective amateur radio operators quickly lose interest when they look at the prices of modern amateur-band transceivers. Often, however, they already own an AM/SSB 27MHz CB radio which they no longer use. These old CB radios have a number of features which make them ideal for use on the amateur bands.

The obvious exception to this is, of course, their frequency range. This is where a transverter can be employed. It's a device that converts transmitted and received RF signals from one band to another. Coupled to a CB radio, it can provide an effective and inexpensive way of getting on to the amateur bands.

In this case, the transverter takes the 27MHz transmitter signal from the CB and converts it to a 12-watt signal on 3.5MHz. Conversely, on receive, it takes the incoming 3.5MHz signals from the antenna and converts them to 27MHz for the CB.

A major advantage of this scheme is that there are no modifications to the CB – the transverter simply plugs in between the antenna socket and the antenna itself. Operation is simply a matter of selecting a channel and talking, as the transverter has an automatic transmit/receive changeover circuit (this can be overridden).

The transverter to be described has an output power of 12W PEP, which is ample during normal conditions on the 80-metre band. It is housed in a neat instrument case with aluminium front and rear panels and runs off 13.8V DC. Inside the case, there are three easy-to-build PC boards and common inexpensive components are used throughout.

The potential problem of ordering an expensive crystal for the mixing frequency has been eliminated by using a novel phase locked loop (PLL) circuit. CB channels are spaced 10kHz apart and the PLL has a ±5kHz fine tune control so that the space between the channels can be used. This provides continuous coverage from

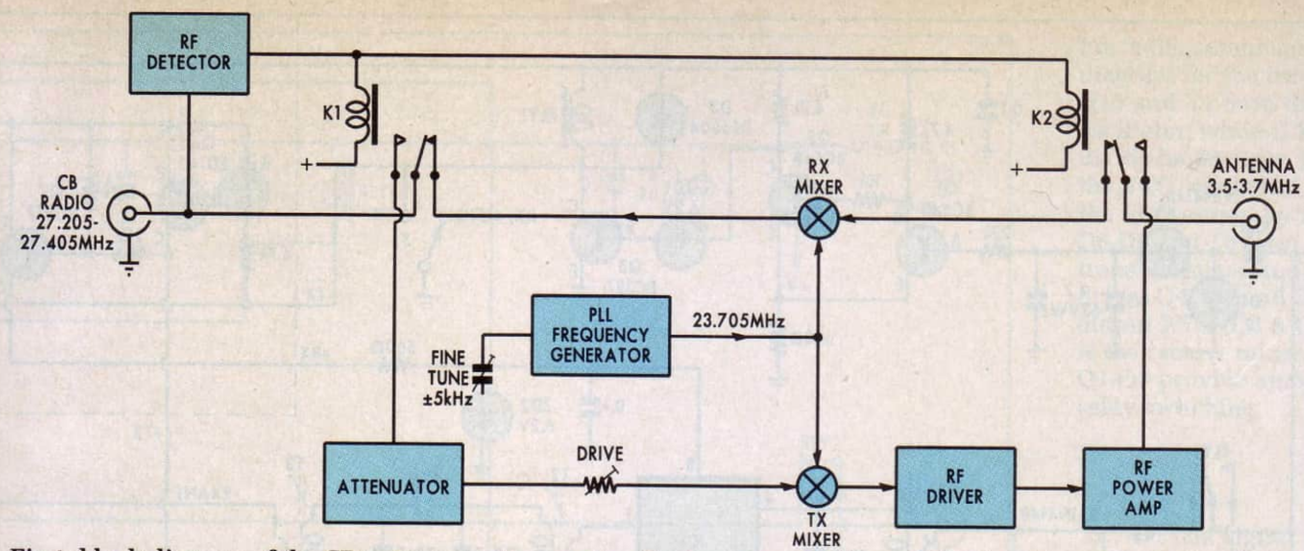


Fig.1: block diagram of the CB to 80-metre transverter. During transmit, the 27MHz signal is attenuated and mixed (in the Tx mixer) with the signal from a PLL frequency generator to produce a difference signal of 3.5MHz. Conversely, in receive mode, the incoming 3.5MHz signal is mixed with the PLL signal in the Rx mixer to produce a difference signal of 27MHz.

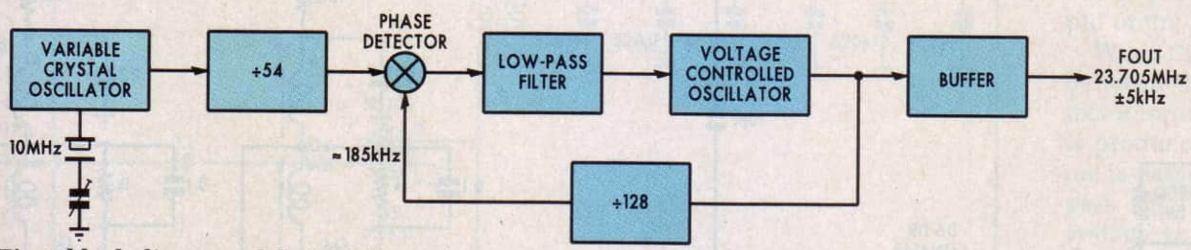


Fig.2: block diagram of the PLL frequency generator section. The output of a 10MHz crystal oscillator is divided by 54 to give a nominal frequency of 185kHz. This signal is then compared in a phase detector with the divided output from a voltage controlled oscillator (VCO) to produce an error signal.

3.500MHz to 3.700MHz.

Working out what frequency you are on is simple. When the CB channel selector is in the 20s, the frequency is between 3.5MHz and 3.6MHz. Similarly, when the channel selector is in the 30s, the frequency is between 3.6MHz and 3.7MHz. This is shown in the channel table (Table 1).

Apart from a mix-up in channels 23, 24 and 25, the scheme works well. From 3.560MHz, the channels remain in sequence to 3.700MHz, with the second channel digit being the 10kHz indicator. Note that 18 and 23-channel CBs transceivers are not suitable because of their limited frequency range.

Block diagram

Fig.1 shows the block diagram of the transverter. When the CB radio starts to transmit, the relays are energised by an RF detector circuit. This directs the 27MHz transmitted signal of about 12W to a dummy load/attenuator. A small amount of the signal is then tapped off by the drive control and fed to a mixer stage.

This mixer stage also accepts a 23.705MHz signal from a PLL frequency generator, giving a difference frequency of 3.5MHz on the output. Finally, this signal is amplified and the resulting 12W output fed via a second relay to the antenna.

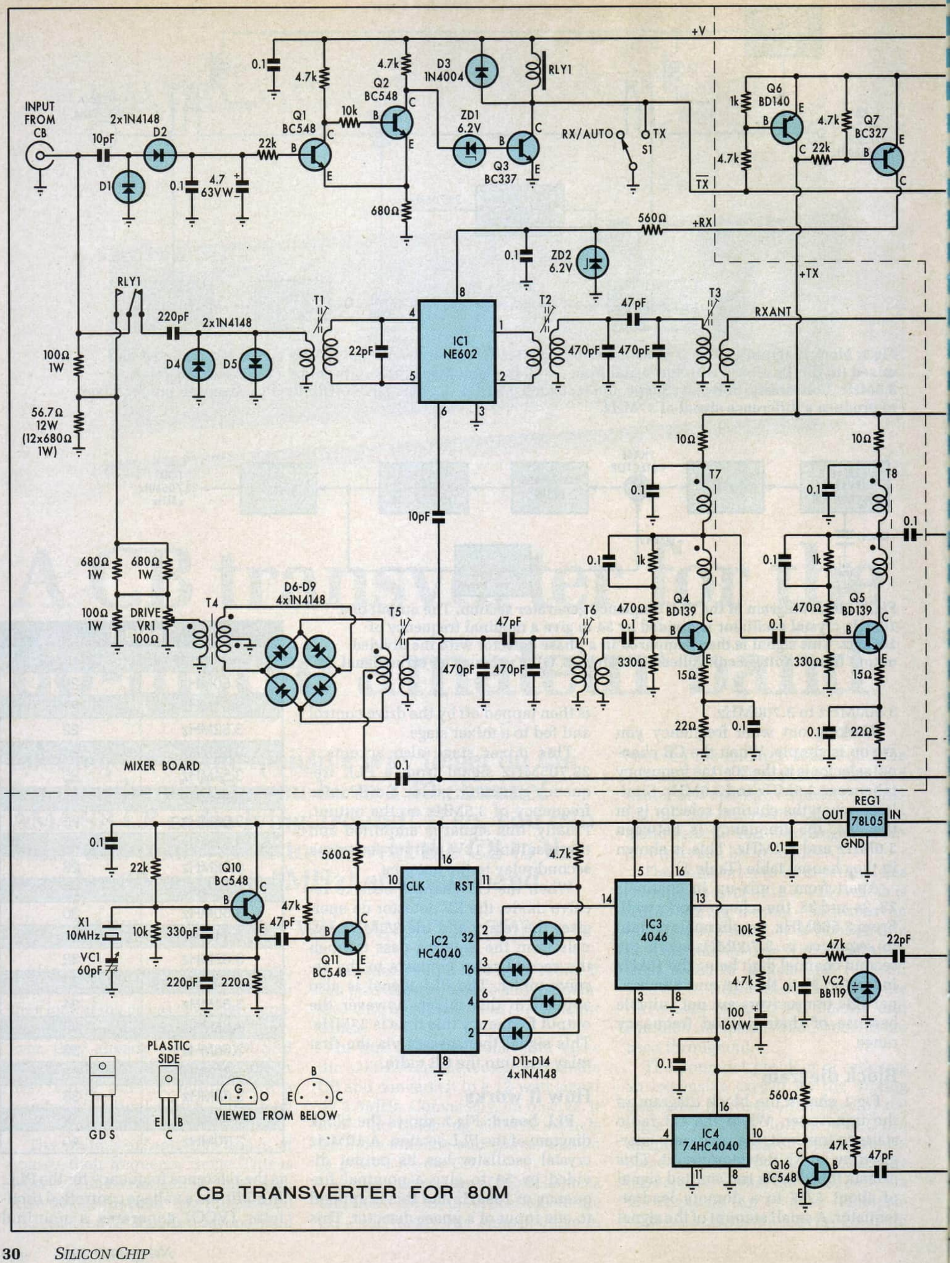
When the CB changes back to receive mode, the RF detector de-energises the relays and the 3.5MHz signals from the antenna pass through the second relay contacts to the receive mixer. The PLL signal is also applied to this mixer, however the output frequency this time is 27MHz. This signal then passes via the first relay and into the CB radio.

How it works

PLL board: Fig.2 shows the block diagram of the PLL section. A 10MHz crystal oscillator has its output divided by 54 to give a nominal frequency of 185kHz and this is applied to one input of a phase detector. This is the reference frequency for the PLL. In addition, a voltage controlled oscillator (VCO) generates a nominal

Table 1

Frequency	Channel
3.50MHz	20
3.51MHz	21
3.52MHz	22
3.53MHz	24
3.54MHz	25
3.55MHz	23
3.56MHz	26
3.57MHz	27
3.58MHz	28
3.59MHz	29
3.60MHz	30
3.61MHz	31
3.62MHz	32
3.63MHz	33
3.64MHz	34
3.65MHz	35
3.66MHz	36
3.67MHz	37
3.68MHz	38
3.69MHz	39
3.70MHz	40



CB TRANSVERTER FOR 80M

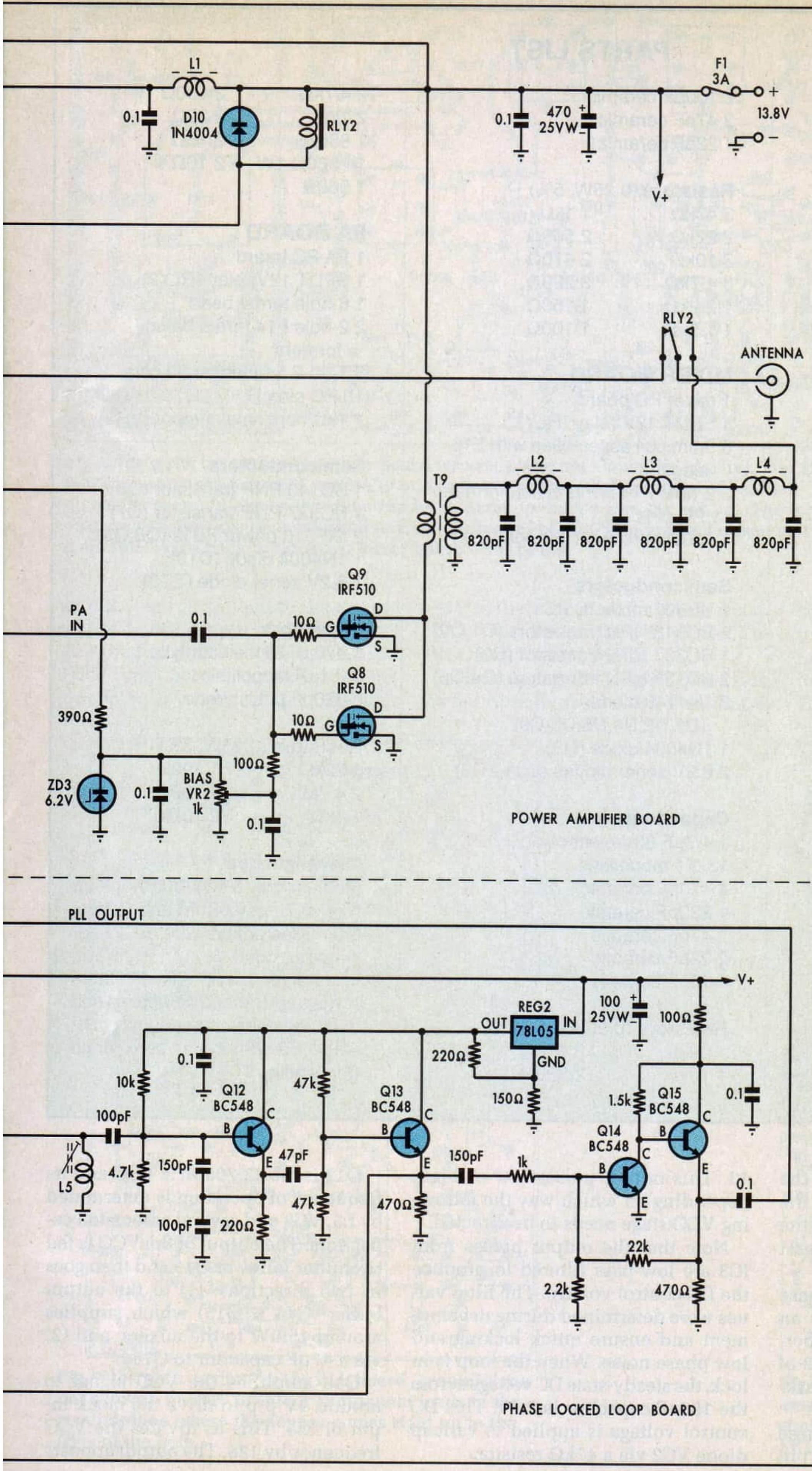


Fig.3: the complete circuit diagram for the transverter. Q10 and X1 form the 10MHz oscillator, while IC2 is the divide-by-54 stage. IC3 is the VCO, while IC4 divides the VCO output by 128. T4, D6-D9 and T5 form the transmit mixer and this drives Q4, Q5 and the two output FETs (Q8 & Q9). IC1 is the receive mixer, while Q1-Q3 provide automatic relay switching.

23.705MHz signal which is buffered and applied to the receive and transmit mixers. The VCO signal is also tapped off and divided by 128 to provide the other input of the phase detector.

When there is a difference between the two phase detector inputs, an error signal is produced. This error signal is passed through a low-pass filter to obtain a DC voltage to change the frequency of the VCO, so that the divided frequency equals the reference frequency.

In practice, the VCO frequency needs to vary from 23.700MHz to 23.710MHz to cover the 10kHz spacing between CB channels. To accomplish this, the 10MHz reference frequency is varied between 9.9984MHz and 10.0027MHz by a series variable capacitor.

Let's have a closer look at how it works – see Fig.3. Q10 and its associated components form the reference oscillator. Feedback is provided by the 220pF and 330pF capacitors, while the 60pF variable capacitor (VC1) trims the 10MHz crystal frequency. The nominal 10MHz signal is taken from Q10's emitter via a 47pF capacitor and amplified by Q11 to provide a 4.5V p-p clock signal for IC2. This IC, a 4040 12-stage binary counter, divides the 10MHz signal by 54.

Diodes D11-14 and their associated 4.7kΩ resistor

PARTS LIST

1 plastic instrument case (Jaybox), 250 x 170 x 75mm
2 binding posts – 1 red, 1 black
1 1-2mm thick aluminium sheet, 240mm x 155mm
2 SO239 panel mount sockets
14 No. 4 x 12mm self-tapper screws
10 6mm long brass spacers
1 SPDT toggle switch (S1)
2 TO-220 insulating washers and bushes
1 in-line fuse holder
1 3A fuse
1 knob

PLL BOARD

1 PLL PC board
1 10MHz crystal (X1)
3 PC pins
1 25mm brass spacer
1 5mm former and F29 slug
1 plastic tuning gang (160pF + 60pF)

Semiconductors
2 74HC4040 12-stage binary counters (IC2,IC4)
1 4046 phase lock loop (IC3)
2 78L05 3-terminal regulators (REG1,REG2)
7 BC548 NPN transistors (Q10-Q16)
4 1N4148 diodes (D11-D14)
1 BB119 varicap diode (VC2)

Capacitors
1 100µF 25V electrolytic
1 100µF 16V electrolytic
7 0.1µF monolithic
1 330pF polystyrene
1 220pF polystyrene
2 150pF ceramic
2 100pF ceramic
3 47pF ceramic
1 22pF ceramic

Resistors (0.25W, 5%)

3 47kΩ	1 1kΩ
2 22kΩ	2 560Ω
3 10kΩ	2 470Ω
3 4.7kΩ	3 220Ω
1 2.2kΩ	1 150Ω
1 1.5kΩ	1 100Ω

MIXER BOARD

1 mixer PC board
1 SPDT 12V relay (RLY1)
5 5mm coil assemblies with F16 slugs
3 2-hole F14 ferrite balun formers
11 PC pins
1 100Ω horizontal trimpot (VR1)

Semiconductors
1 NE602 mixer IC (IC1)
2 BC548 NPN transistors (Q1,Q2)
1 BC337 NPN transistor (Q3)
2 BD139 NPN transistors (Q4,Q5)
8 1N4148 diodes (D1,D2,D4,D5,D6-D9)
1 1N4004 diode (D3)
2 6.2V zener diodes (ZD1,ZD2)

Capacitors
1 4.7µF 63V electrolytic
13 0.1 monolithic
4 470pF ceramic
1 220pF ceramic
2 47pF ceramic
2 22pF ceramic
1 10pF ceramic

Resistors (0.25W, 5%)

1 22kΩ	2 470Ω
1 10kΩ	2 330Ω
2 4.7kΩ	2 100Ω 1W
2 1kΩ	2 22Ω
1 680Ω	2 15Ω
14 680Ω 1W	2 10Ω
1 560Ω	

PA BOARD

1 PA PC board
1 SPDT 12V relay (RLY2)
1 6-hole ferrite bead
2 2-hole F14 ferrite balun formers
3 T-50-2 Amidon toroid core
10 PC pins
1 1kΩ horizontal trimpot (VR2)

Semiconductors
1 BD140 PNP transistor (Q6)
1 BC327 PNP transistor (Q7)
2 IRF510 power FETs (Q8,Q9)
1 1N4004 diode (D10)
1 6.2V zener diode (ZD3)

Capacitors
1 470µF 25V electrolytic
5 0.1µF monolithic
6 820pF polystyrene

Resistors (0.25W, 5%)

1 22kΩ	1 390Ω
2 4.7kΩ	1 100Ω
1 1kΩ	2 10Ω

Miscellaneous
Medium-duty & light-duty hook-up wire; 0.7mm, 0.4mm and 0.2mm enamelled copper wire (ECW) for winding coils & transformers; tinplate for metal shields; 2mm screws and nuts; 3mm screws and nuts; heatsink compound; miniature 50-ohm coax; coax braid (for winding T9)

form an AND gate. In operation, the diode anodes remain low until the count reaches 54. At this point, the anodes go high, the counter is reset and the process starts again.

IC3 is a 4046 PLL but only its phase detector section is used. This is an edge-triggered type, which is important because the signal from pin 2 of IC2 does not have an equal mark/space ratio.

Pin 3 is the other input to the phase comparator, while the output is at pin 13. This output pulses low or high, depending on which way the following VCO stage needs to be directed.

Note that the output pulses from IC3 are low-pass filtered to produce the DC control voltage. The filter values were determined during development and ensure quick locking and low phase noise. When the loop is in lock, the steady-state DC voltage across the 100µF capacitor is 2.5V. This DC control voltage is applied to varicap diode VC2 via a 47kΩ resistor.

Q12 is the 23.705MHz VCO and its frequency of operation is determined by L5, VC2 and several associated capacitors. The output of the VCO is fed to emitter follower Q13 and then goes in two directions: (1) to the output buffer (Q14 & Q15) which supplies around 15mW to the mixers; and (2) via a 47pF capacitor to Q16.

Q16 amplifies the VCO signal to around 4V p-p to drive the clock input of IC4. This IC divides the VCO frequency by 128. The output appears

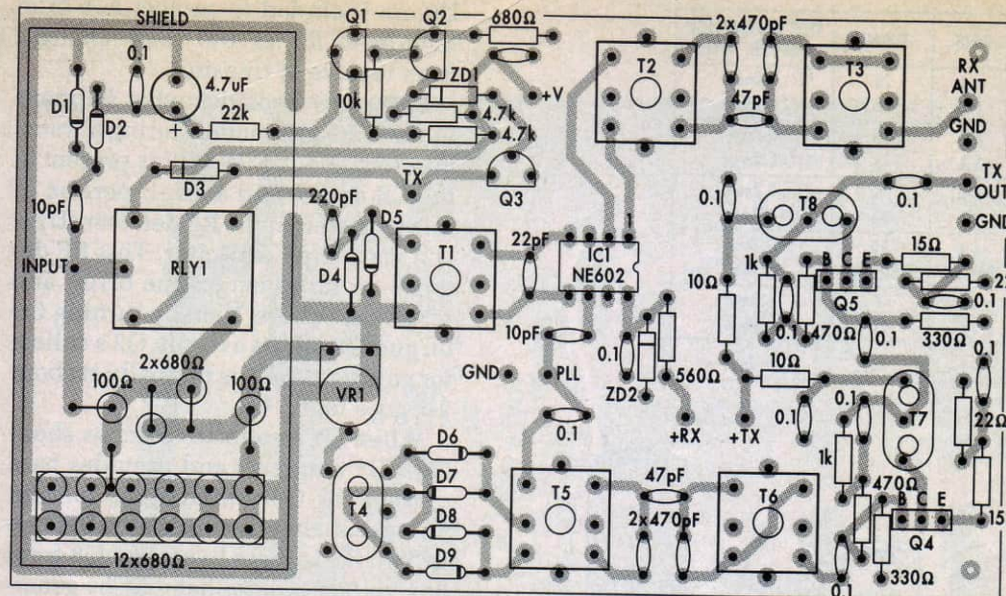


Fig.4: the parts layout for the mixer board (groundplane not shown for clarity). The 12 680Ω resistors are mounted vertically on the board and need about 5mm of lead left above the groundplane so that they can be soldered to the top and the bottom. The tops of these resistors are then soldered to a small piece of blank PC board and a lead run from this board back to the main mixer board – see photo.

at pin 4 and is applied to the second phase detector input of IC3. Note that IC2 and IC4 must be high-speed CMOS (HC) types because of the clock frequencies involved. REG1 provides +5V to the logic circuits, while REG2 is "jacked up" to 8.5V to power the VCO and it's Q13 buffer.

The output buffer stage (Q14 & Q15) is fed directly from +13.8V so that it can develop the output power required.

In summary, the PLL frequency generator circuit effectively multiplies the 10MHz crystal oscillator frequency by the ratio of the two dividers – ie, 128/54 or 2.37037 – to obtain the output frequency of 23.705MHz. There are two points to note about this. First, to obtain the required 10kHz shift in the VCO frequency, we only need to move the oscillator frequency by 4.2kHz. Second, any drift in the reference oscillator will be multiplied by 2.37037 in the VCO. That is why polystyrene capacitors are specified in the 10MHz oscillator circuit.

Mixer board: Let's now take a look at the mixer board circuitry. In the receive mode, the signals from the antenna are first passed via the NC (normally closed) contacts of RLY2 to a bandpass filter stage based on T3 and T2. These reject strong out-of-band

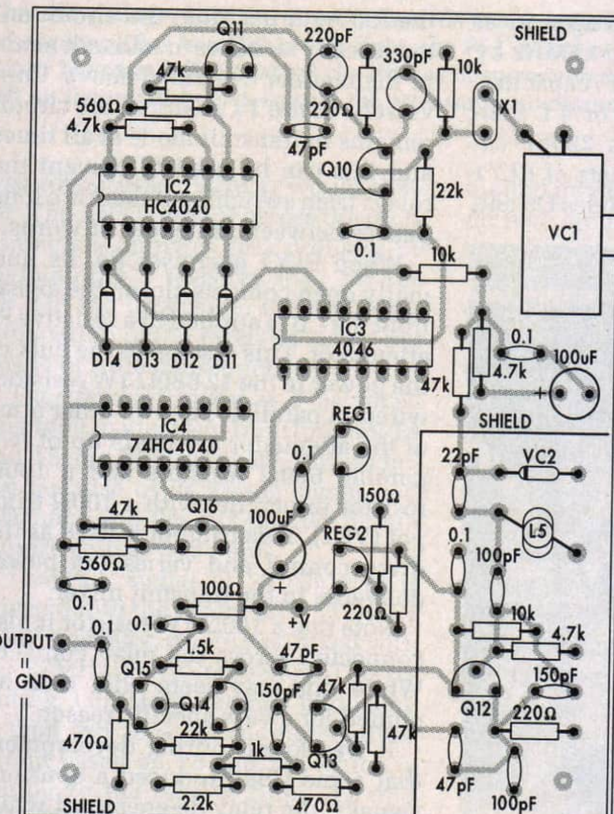


Fig.5: the parts layout for the PLL board (groundplane not shown). Be sure to solder component leads to the groundplane where the copper comes right up to the edge of the hole.

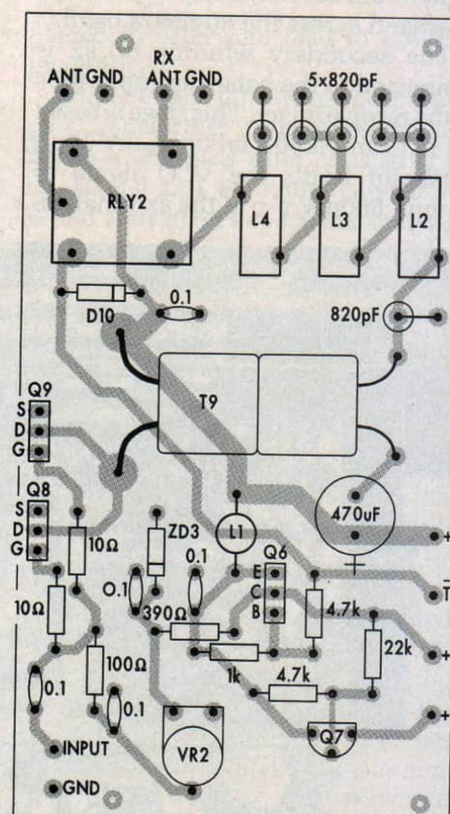
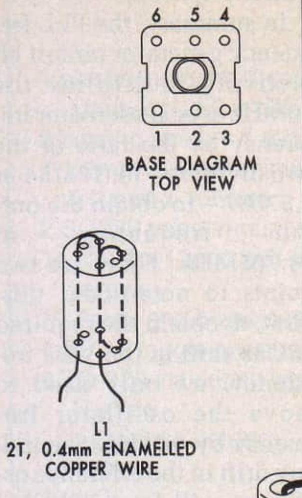
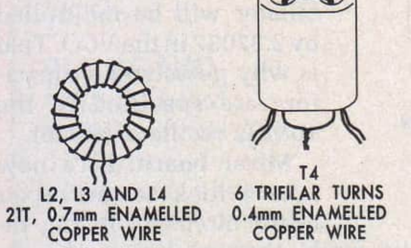


Fig.6: the parts layout for the power amplifier board (groundplane not shown). Make sure that the two power FETs (Q8 & Q9) are correctly oriented.



WINDING	PINS	TURNS	SIZE ENAMELLED COPPER WIRE
T1	4-6 1-3	15 3	0.2mm 0.2mm
T2	4-6 1-3	30 15	0.2mm 0.2mm
T3	4-6 1-3	4 30	0.2mm 0.2mm
T5	4-6 2-1CT-3	30 8 BIFILAR	0.2mm 0.2mm
T6	4-6 1-3	4 30	0.2mm 0.2mm
L5	—	12	0.4mm



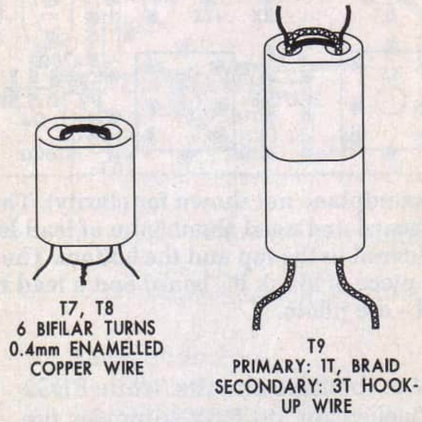


Fig.7: here are the winding details for the various transformers and coils. Further details on the winding procedures are given in the text.

signals and are tuned to provide a flat passband across the 80-metre band.

The secondary winding of T2 is connected to the balanced input pins of the receive mixer. This stage is based on IC1, an NE602 mixer IC. A 10pF capacitor limits the VCO signal to around 500mV p-p at the external oscillator input (pin 6).

The output of the mixer appears at pins 4 & 5 and is tuned to 27MHz by T1 and its parallel 22pF capacitor. The secondary winding of T1 then couples this signal via a 220pF capacitor and the NC contacts of RLY1 to the CB radio socket. Diodes D5 and D6 are included to protect IC1 from high-level RF as the relay changes from receive to transmit.

Let's now consider what happens in the transmit mode. During a transmission, about 12W PEP is present at the CB socket and a small portion of this is passed to the RF detector (D1 & D2) via a 10pF capacitor. This RF detector in turn charges the 0.1µF and 4.7µF capacitors, thereby turning Q1 on and Q2 off. As a result, Q2's collector voltage, which is normally at about 2V, goes high.

When Q2's collector reaches about 7V, ZD1 conducts and provides base current for Q3 which turns on and energises the two relays (RLY1 & RLY2). D3 is there to protect Q3 from any voltage spikes that may be generated by the relay coils. When there is no RF, the 4.7µF capacitor discharges via the 22kΩ resistor and the base of Q1. This produces a delay in the relay releasing and eliminates relay chatter in between words.

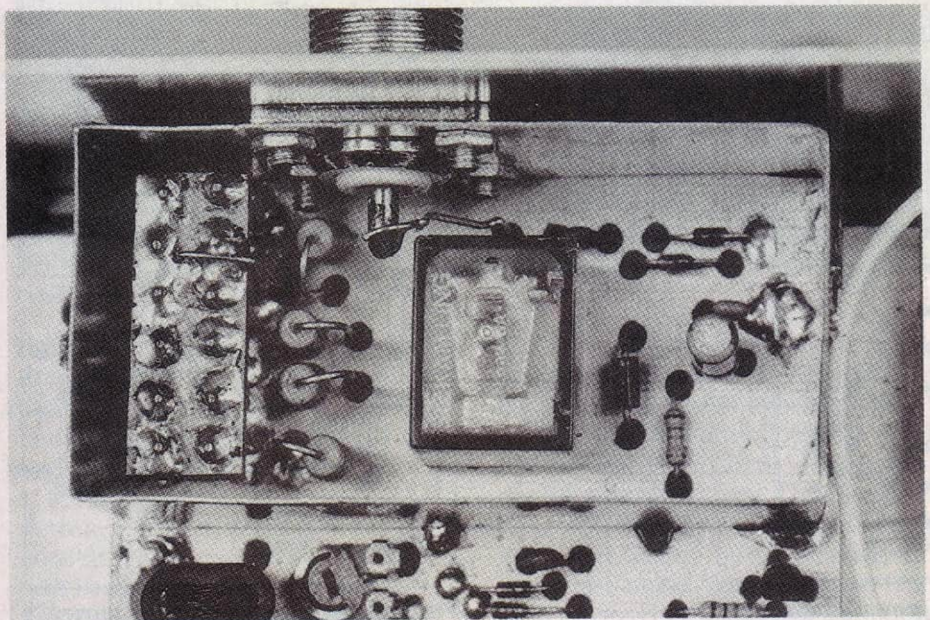
If the delay needs to be increased, it's simply a matter of increasing the 22kΩ resistor. Conversely, the 22kΩ resistor should be decreased if the delay proves to be too long.

Switch S1 is the Rx/Tx switch. In the Rx/Auto position, the circuit automatically switches to transmit mode in the manner described above. Conversely, in the Tx position, the circuit remains in transmit mode at all times and this can be used to prevent the relays from switching if there are long pauses between sentences or words.

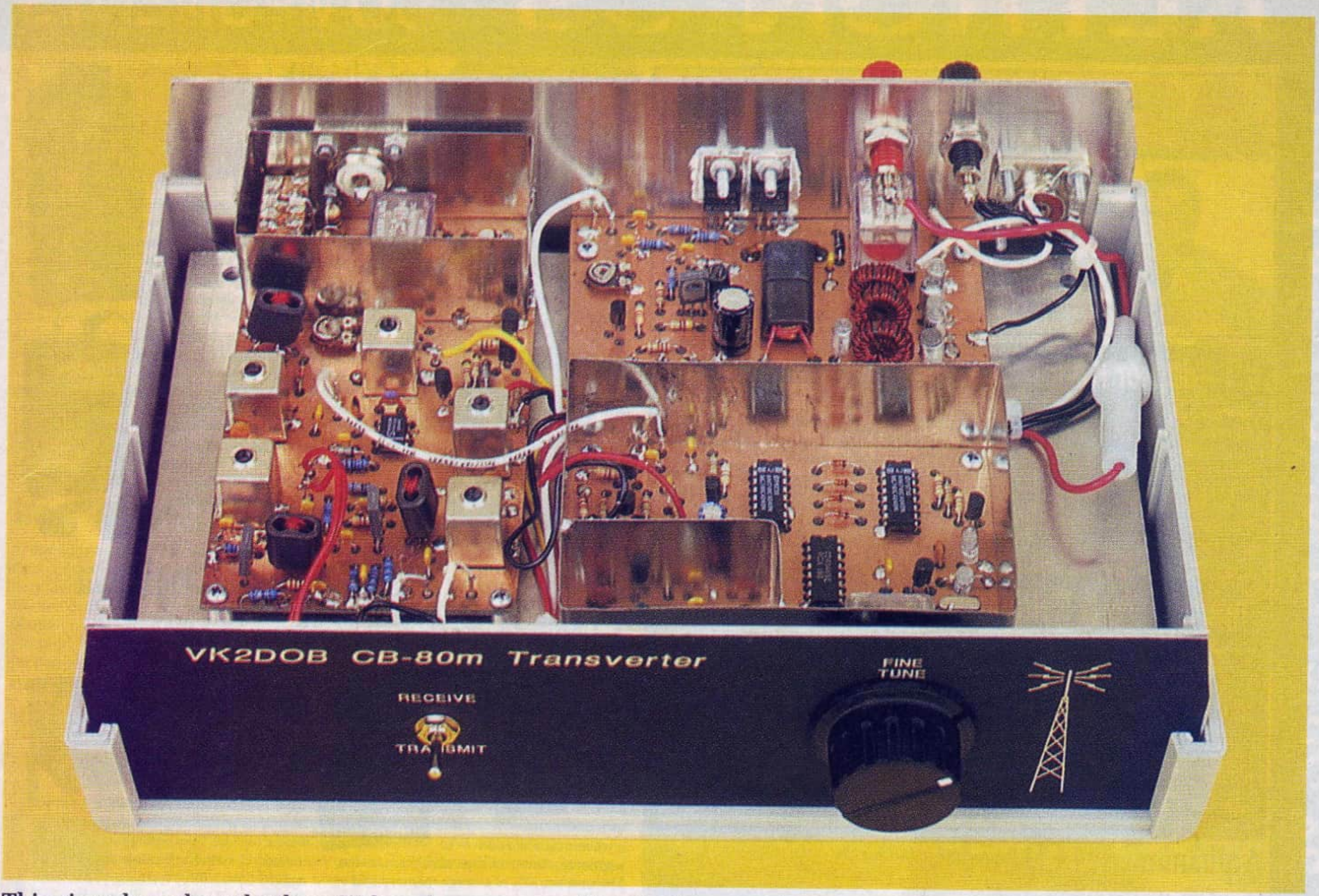
When RLY1 energises (ie, its normally open contacts close), the signal from the CB is applied to a resistive Pi attenuator. This dissipates the bulk of the power in the 12 680Ω 1W resistors wired in parallel. The two other arms of the attenuator are made up of two parallel 680Ω resistors and a 100Ω resistor in parallel with a 100Ω trimpot (VR1). This trimpot is used as the drive control and varies the power delivered to the transmit mixer.

Note that a 100Ω 1W resistor is also connected across the relay contacts. While this may seem odd, it is included for a very specific reason.

It was found during development that some CBs produced a spurious signal if the relay de-energised while the push-to-talk (PTT) button was held down (ie, if there was no speech input). This caused the RF detector to energise the relay again and if the PTT



This close-up view shows what's inside the shielded section on the mixer PC board. The 12 680Ω attenuator resistors are at the far left, while relay RLY1 is at the centre. Note that this shielded area is normally fitted with a metal lid.



This view shows how the three PC boards are arranged inside the case. The power amplifier board is at top right, the PLL board at bottom right and the mixer board at left. Note that the lid has been removed from the shield at top left on the mixer board, so that the attenuator components can be seen

was not released, the relay would chatter. The 100Ω resistor across the relay contacts eliminates this problem by maintaining a resistive load for the CB. On the downside, there is some attenuation of the received signal but this is of little consequence.

The transmit mixer is a balanced ring type made up of transformers T4 and T5 and diodes D6-D9. It was chosen because of its strong signal performance and the fact that we do not require gain at this point.

The PLL signal at 23.705MHz is injected into the centre tap of T5 via a 0.1μF capacitor, where it is mixed with the 27MHz drive frequency. The resulting 3.5MHz difference frequency is then fed to a double-tuned filter circuit based on T5 and T6, which is similar to the receive filter (T2 and T3). The filtered low-level 3.5MHz signal is then amplified by two identical broadband amplifiers based on Q4 and Q5. These two stages have considerable negative feedback to ensure stable and predictable performance. They deliver around 100mW to the final amplifier stage.

Power amplifier board: The remainder of the circuitry is accommodated on the power amplifier board. Transistors Q6 & Q7 provide the transmit/receive switching. When the TX-bar line from Q3 is high (ie, Q3 is off), Q6 is turned off and so Q7 turns on. Q7 then supplies power to the receive mixer (IC1) on the mixer board.

Conversely, when the TX-bar line goes low, transistor Q6 turns on and Q7 turns off. Q6 now supplies power to the transmit driver stages (Q4 & Q5) and to bias trimpot VR2. Zener diode ZD3 is included to ensure that the bias voltage does not vary during transmit.

The output devices consist of power FETs Q8 and Q9, which are connected in parallel. Their gates are DC biased to around 3.8V by VR2 and this results in a typical quiescent current of 200mA per device. A 10Ω resistor is placed in each gate lead to prevent instability.

Immediately following the output pair, transformer T9 couples the signal to a low-pass filter consisting of L2, L3, L4 and six 820pF capacitors. When viewed on a spectrum analyser, all harmonics and spurious components were at least 55dB below the wanted signal. Relay RLY2 switches the antenna between the receive mixer (during receive mode) and the output low pass filter (during transmit mode).

Power for the circuit is derived directly from a suitable 13.8V supply. A 3A fuse is included in the supply lead as a precaution against short circuits.

Construction

This design is built on three double-sided PC boards. On each of these, the top side carries a continuous copper groundplane except for clearances around most of the component holes. However, some component leads must be soldered directly to the groundplane. These leads will be obvious since the groundplane copper will come right up to the edge of the holes.

The exceptions here are the electro-

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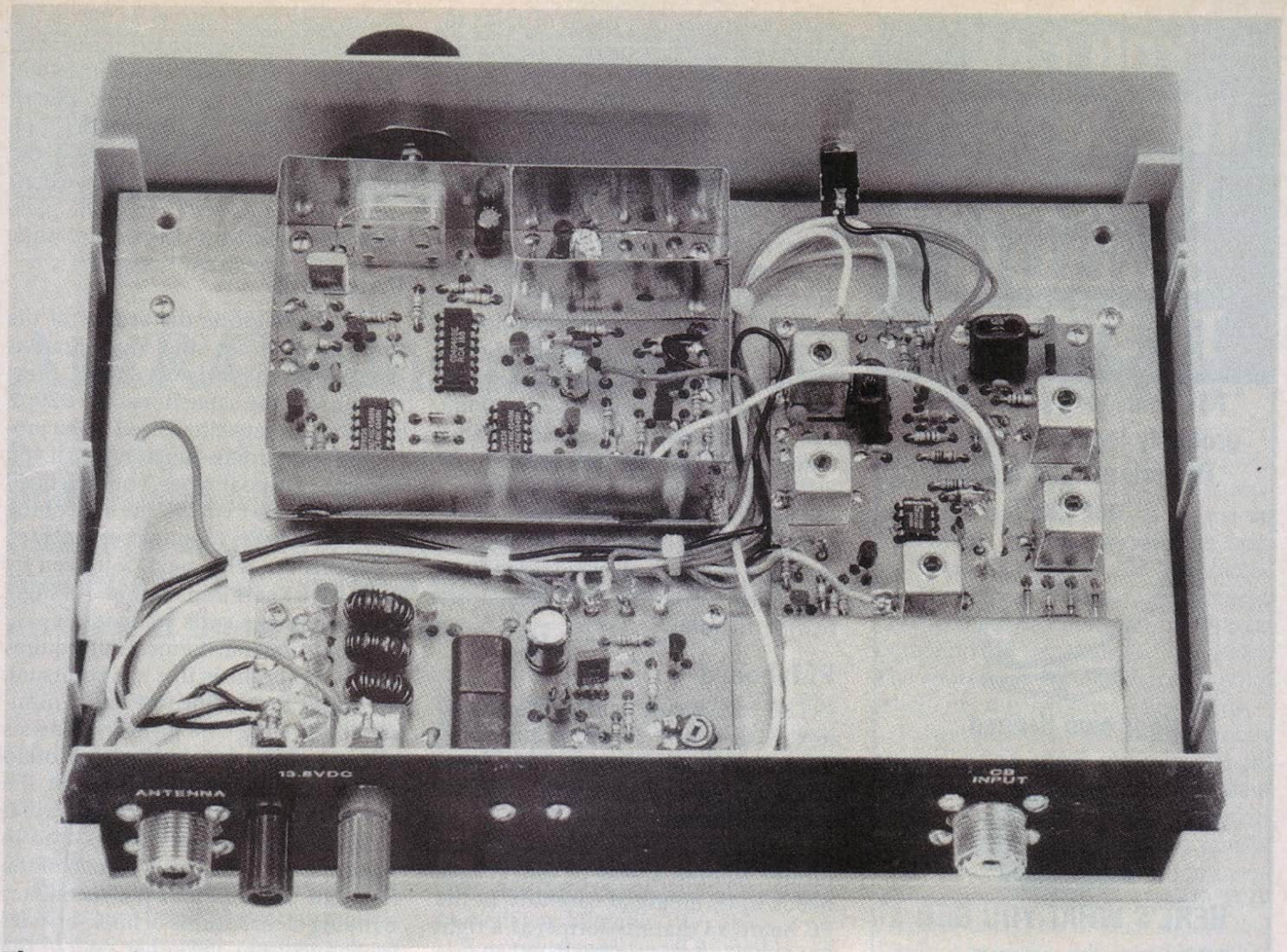

The rear of the transverter carries the antenna socket, two power supply binding posts and the input socket (which connects to the CB radio). Note that the three boards are mounted on a metal baseplate.

lytic capacitors which get their earth connections via the leads of adjacent components, which are themselves soldered on the top and bottom of the board.

Fig.4 shows the parts layout on the mixer board. Install the resistors and PC pins first. The 12 680Ω resistors that make up the dummy load are soldered vertically and need about 5mm of lead left above the groundplane so that they can be soldered to the top and the bottom.

A small piece of scrap PC board is cut out and drilled to fit over the top of the resistors – see photo. The leads are soldered to this piece and a wire is soldered from it to the track under the board. The other 1W resistors are also mounted vertically on the board, as shown on Fig.4.

The capacitors can be soldered in next. Make sure that their leads are kept short and be careful not to short any leads to the groundplane as they pass through the holes. Now solder in the relay, followed by the coils and transformers. Fig.7 shows the coil winding details.

The tuned transformers are made up of a 6-pin base and former, a metal can and a ferrite slug. Transformers T1, T2, T3 and T6 each consist of two windings soldered to the relevant pins. The larger winding is wound first, with the second winding wound over it towards the bottom of the former.

T7 and T8 are bifilar wound on F14 ferrite balun formers. Two wires, each 400mm long, are twisted together until there are about five twists per centimetre. The combined wires are then wound six times through the centre of the balun former – ie, up one hole and down the other. The ends all appear at the same end of the former.

Scrape the enamel off the ends of the wires and identify the windings with a continuity tester. The start of one winding and the end of the other winding forms the centre tap.

Transformer T4 is similar except that it is trifilar wound (ie, it uses three twisted wires). Two of the windings are connected as before, while the third winding becomes the primary. Tuned transformer T5 is a hybrid combination of a standard secondary winding with a bifilar primary winding wound around the top of the secondary.

Fig.3 indicates the phasing of the windings with black dots. In each case, this phasing must be correct, otherwise the circuits will perform poorly or not at all.

The tuned winding cans are soldered directly to the groundplane, while the balun formers mount vertically with the winding ends facing the PC board. When this is complete, install the semiconductors, making sure that they are correctly oriented.

Note that the diodes in the transmit mixer (D6-D9) should be a matched set. This involves measuring the forward resistance of a batch of 1N4148 diodes with a multimeter. Choose the four that have the closest readings.

As can be seen in the photographs, the dummy load area has a 30mm high metal screen installed around it. This is necessary to ensure that the 27MHz signals do not get radiated. A cover needs to be soldered on top, however this should be left until after the board has been mounted in the case and testing has been completed.

The screen can be made from copper, brass shim or tinplate (as used in the prototype). It measures 35 x 70mm and is soldered to the groundplane. Before it is mounted, holes need to be drilled to match the SO239 socket. This socket needs to be offset to allow the centre pin to pass by the side of the relay. A wire is then soldered from the centre pin to the PC board at the rear of the relay.

PLL board

The PLL board can be assembled next – see Fig.5. Begin by installing the resistors and PC pins. This done, install the capacitors, diodes, transistors, ICs and the crystal.

The VCO coil (L5) is wound on a former without a base or can. A hole needs to be enlarged carefully in the PC board so that the former is a tight fit. A drop of Super Glue® will ensure that it stays there. Wind the coil tightly onto the former and coat it with silicone adhesive or similar to ensure that the winding does not move, to avoid microphonics.

A 30mm high screen is soldered around this PC board about 1-2mm in from the edge. In addition, a separate 30mm high L-shaped piece (48 x 25mm) is soldered around the VCO section. A top cover is not required for this board.

Before the outer screen is soldered on, it is necessary to drill mounting holes for the variable capacitor (VC1). This variable capacitor mounts with its side resting on the board and its leads pointing towards the crystal. Once the holes have been drilled, install the shield, then mount VC1 in position. Two wires can now be soldered between VC1's leads and the board – one from the top lead to the crystal and the other from the middle to the groundplance.

A shaft extension needs to be manufactured for VC1. The technique finally adopted is to carefully solder a 25mm-long brass spacer at 90° to the centre of a piece of tinplate measuring 20 x 35mm. Two holes are then drilled in the tinplate (one on either side of the spacer) and the flat plastic knob that comes with VC1. Finally, the tinplate piece, with the shaft extension attached, is fastened to the plastic knob using 2mm screws and nuts.

PA board

The PA board is the easiest of the three to construct – see Fig.6. Start as before with the resistors and PC pins, then install the capacitors. The 820pF polystyrene capacitors used in the prototype were single-ended types. If you can only get axial types, you will need to bend one lead down the side of the body so that they mount vertically.

Mount the relay next, followed by coils L1-L4 and transformer T9. Fig.7 shows how the coils are made.

The output transformer (T9) requires special mention as it is a bit unusual. It is made by placing two balun formers end-to-end. The primary consists of a piece of good quality coax braid which is first threaded through the holes to form a single turn. A scriber or similar implement is then used to poke a hole in the braid at each of the four exit points. Finally, a secondary winding of three turns of hook-up wire is wound from the other end of the formers, with the turns fed through these holes and passing up and down inside the centre of the braid.

Care is required during this procedure to avoid shorts between the windings, because when power is applied the primary is at +13.8V and the secondary is at ground potential. This is the main reason why enamelled copper wire is not used. Teflon coated wire would be preferable, although normal hook-up wire has proven successful. Use the largest size of wire possible.

The holes in the board for the primary winding will need to be enlarged to pass the braid. Make sure that none of the braid can touch the groundplane. Finally, solder in the semiconductors, with the two output FETs (Q8 & Q9) mounted about 5mm above the board. This makes it easier to solder their source leads to the top of the board.

That's all we have space for this month. Next month, we shall complete the wiring and give the test and alignment procedures. SC