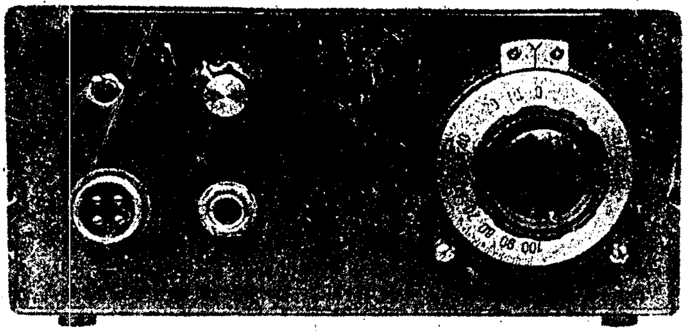
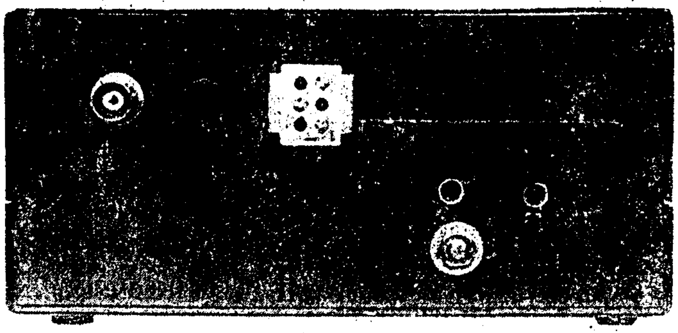
A QRP TRANSCEIVER FOR 1·8MHz



Front view of transceiver. On this prototype the TUNE switch is labelled TEST



Rear view of transceiver

*S E Hunt, Msc G3TXQ**

Introduction

This transceiver was developed as part of a 1·8MHz portable station, the other components being a QRP atu, a battery-pack and a 200ft kite-supported antenna. It would be a good constructional project for the new Class A licensee or for anyone whose station lacks 1·8MHz coverage. The 2W output level may seem a little low, but it results in low battery drain and is adequate to give many 1·8MHz contacts.

I make no claim for circuit originality. Much of the design was adapted from other published circuitry, particularly from the designer's "bible"—*Solid-State Design for the Radio Amateur* (ARRL). However, I do claim that the design is repeatable—six transceivers have been built to this circuit and have worked first-time. Repeatability is achieved by extensive use of negative feedback; this leads to lower gain-per-stage (and therefore the need for more stages) but makes performance largely independent of transistor parameter variations.

Circuit description (Fig 1)

The transceiver comprises a direct-conversion receiver together with a double-sideband (dsb) transmitter. This approach results in much simpler equipment than a superhet design, and is capable of surprisingly good performance, particularly if care is taken over the mixer circuitry.

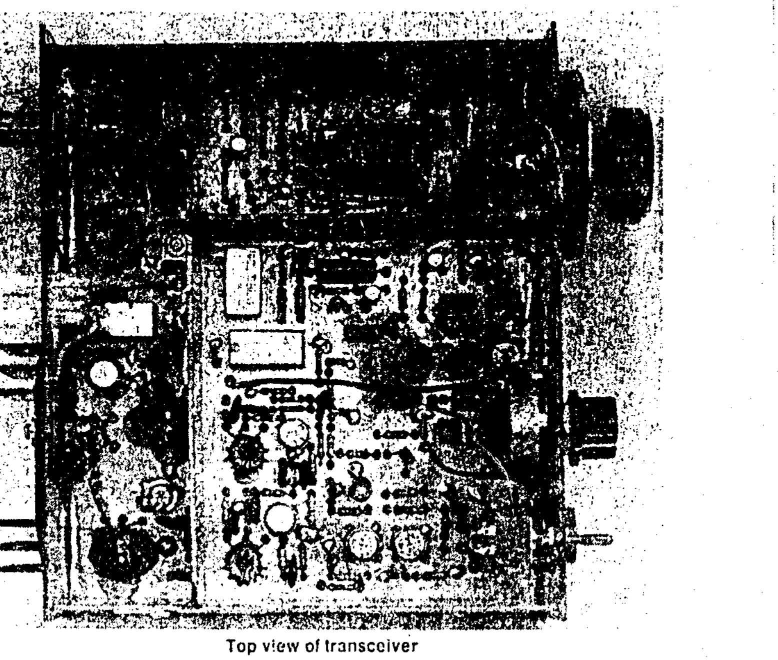
During reception, signals are routed through the bandpass filter (L1, L2 and C25–C31) to a double-balanced mixer, M1, where they are translated down to baseband. It is vital for the mixer to be terminated properly over a wide range of frequencies, and this is achieved by a diplexer comprising R34, RFC2 and C32–C34. Unwanted rf products from the mixer, rejected by RFC2, pass through C32 to the 47Ω terminating resistor R34. The wanted audio products pass through RFC2 and C34 to a common-base amplifier stage which is biased such that it presents a 50Ω load impedance. The supply rail for this stage comes via an emitter-follower, TR5, which has a long time-constant (4s) RC circuit across its base. This helps to prevent any hum on the 12V rail reaching TR6 and being amplified by IC3.

The voltage gain of the common-base stage (about ×20) is controlled by R37 which also determines the source resistance for the following low-pass filter (L3, L4 and C39–C43). This filter is a Chebyschev design and it determines the overall selectivity of the receiver. The filter is followed by a single 741 op-amp stage which gives adequate gain for headphone listening; however, an LM380 audio output stage can easily be added if you require loudspeaker operation.

Steve Hunt was born in 1947 and became interested in amateur radio as a teenager when he was given a crystal set for Christmas. He was licensed at the age of 17, and began operating on 1·8MHz using a home-built copy of the Codar AT5 transmitter and an HRO receiver. He is a professional electronics engineer, having studied at Hendon College of Technology under sponsorship from the BBC, and later at Birmingham University. His main interests are home-construction and 1·8MHz, mobile and portable operation.

On transmit, audio signals from the microphone are amplified in IC1 and IC2, and routed to the double-balanced mixer where they are heterodyned up into the 1·8MHz band as a double-sideband suppressed-carrier signal. Capacitors C56 and C57 cause some high-frequency roll-off of the audio signal and thereby restrict the transmitted bandwidth. A 6dB attenuator (R12–R14) provides a good 50Ω termination for the mixer. The dsb signal is amplified by two broadband feedback amplifiers, TR2 and TR3, each having a gain of 15dB. TR3 is biased to a higher standing current to keep distortion products low.

The pa stage is a single-ended design by VE5FP (1). The inclusion of unbypassed emitter resistors R30–R32 establishes the gain of the pa and also helps to prevent thermal runaway by stabilising the bias point. Additional rf negative feedback is provided by the shunt feedback resistor R29. I chose to run the pa at a moderately high standing current (330mA) in order to reduce distortion products, thinking that at some stage I might use the transceiver as a "driver" for a 10–15W linear amplifier. The pa output (about 2W p.e.p) is routed through the bandpass filter to the antenna. I used a 2N3632 transistor in the pa because I happened to have one in the junk-box; the slightly less expensive 2N3375 would probably perform just as well. VE5FP used a 2N5590 transistor but this would need different mounting arrangements.



Top view of transceiver

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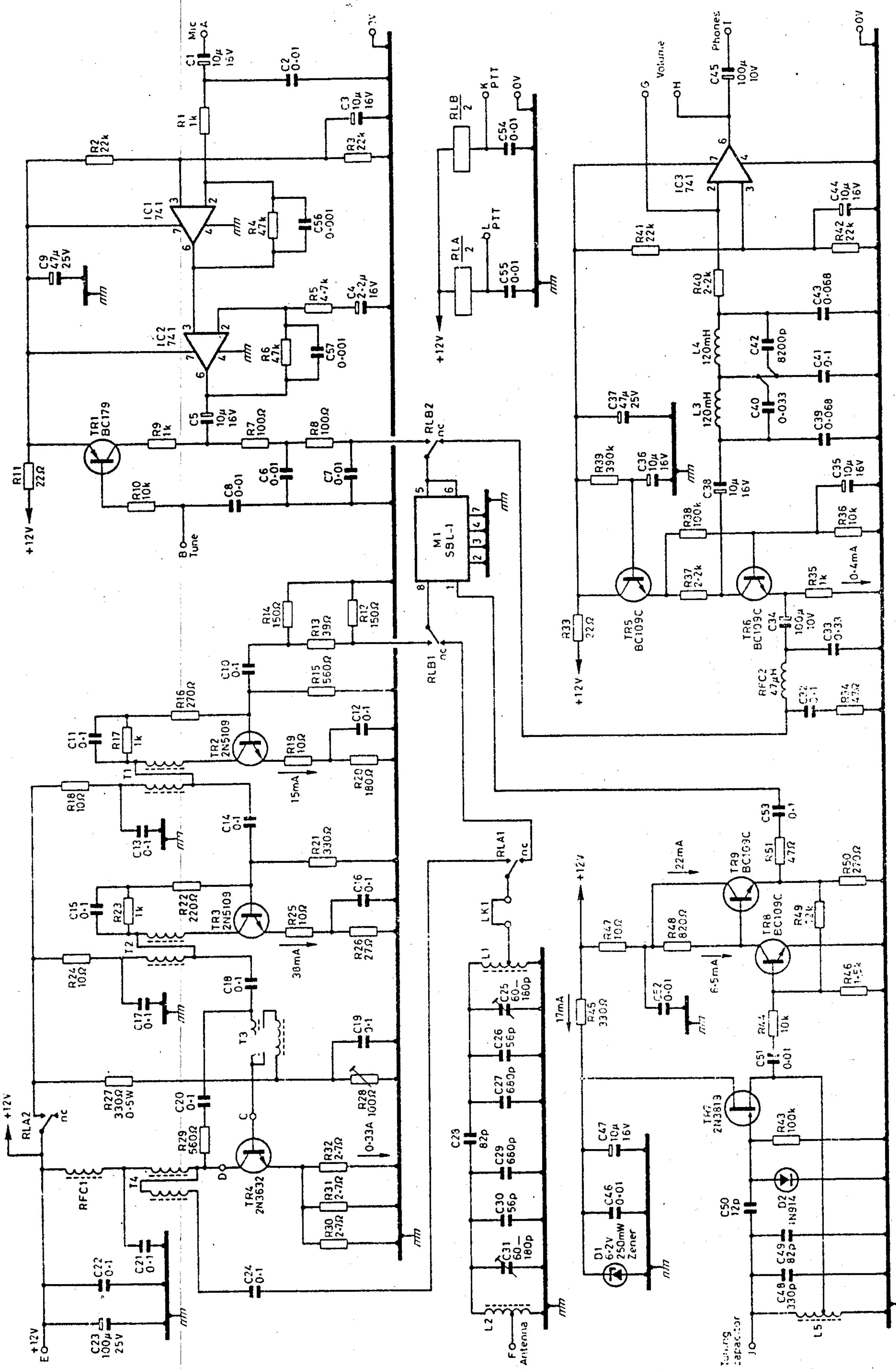


Fig 1. Circuit diagram

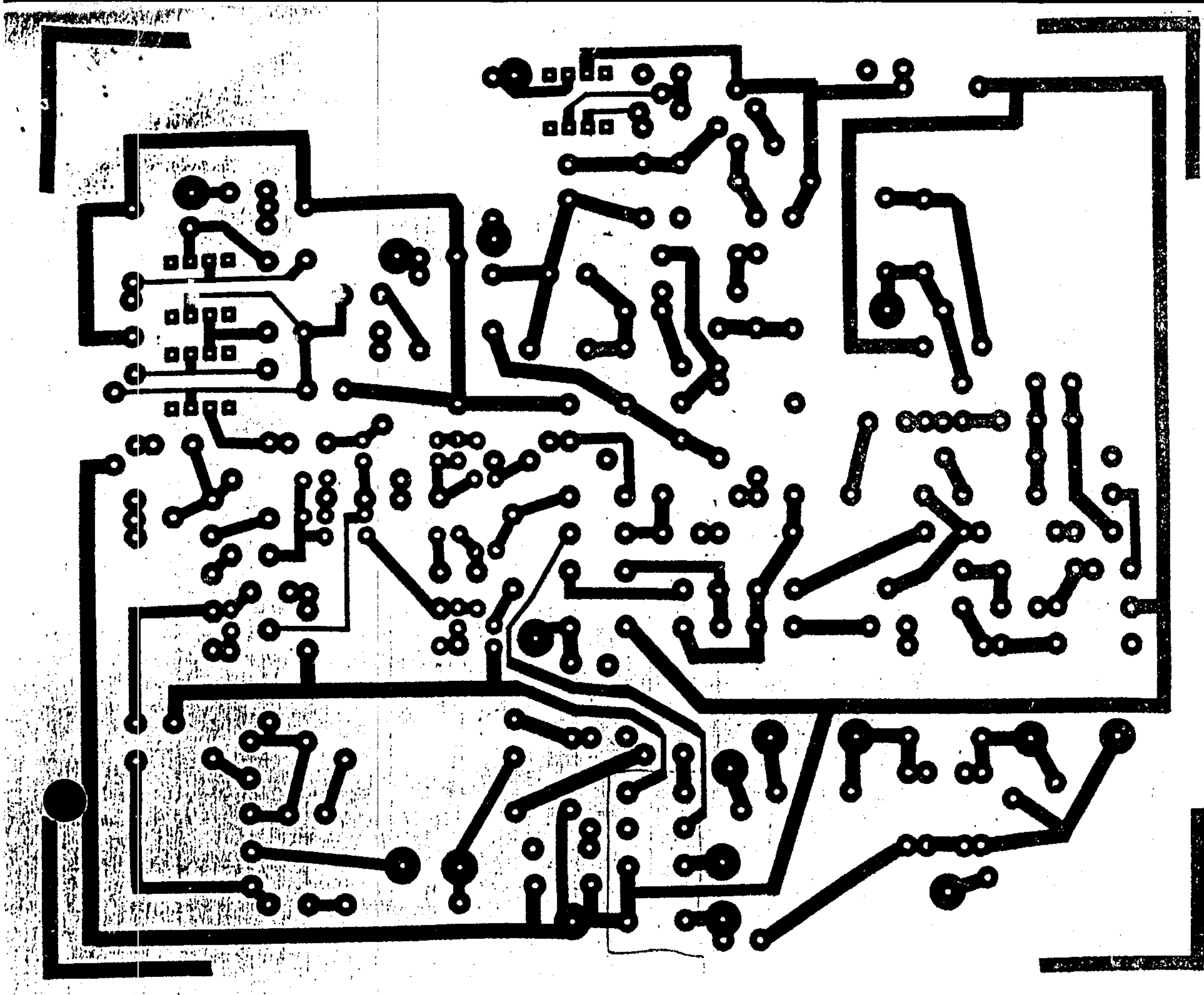


Fig 2. PCB layout

At the heart of the transceiver is a Hartley vfo comprising TR7 and associated components. The supply to this stage is stabilised at 6·2V by zener diode D1 and decoupled by C46 and C47. It is important for best stability that the "type 6" core material is used for L5 as this has the lowest temperature coefficient of permeability. Output from the vfo is taken from the low impendance tap on L5.

The vfo buffer is a feedback amplifier comprising TR8 and TR9. The input impedance of this buffer is well-defined by R44 and presents little loading of the vfo. Its gain is set by the ratio R49/R44, and R51 has been included to define the source resistance of this stage at approximately 50Ω.

Change-over between transmit and receive is accomplished by two dpdt relays which are energised when the ptt lines are grounded. A cw signal for tuning purposes can be generated by grounding the TUNE pin—this switches on TR1, which in turn unbalances the mixer, allowing carrier to leak through to the driver and pa stages.

Construction

The transceiver is constructed on a single 6 by 5in pcb. The artwork, component layout and wiring diagram are shown in Figs 2–4 respectively. The pcb is double-sided—the top (component) surface being a continuous groundplane of unetched copper.

Without the facility to plate-through holes, some care needs to be taken that components are grounded correctly. Where a component lead is not grounded, a small area of copper must be removed from the groundplane, using a "spot-cutter" or a small twist drill. Where a component lead needs to be grounded, the copper should not be removed and the lead should be soldered to the groundplane as well as to the pad on the underside. This is easy to achieve with axial-lead components (resistors, diodes etc) but can be difficult with radial-lead components. In most cases the pcb layout overcomes this by tracking radial leads to ground via nearby resistor leads. A careful look at the circuit diagram as each component is loaded will soon show what is needed.

Remember to put in a wire link between pins L and K, and in position LK1. I used screened cable for connecting pins G and H to the volume control—connect the outer to pin H. There are no pcb pads for C56 and C57, so these capacitors should be soldered directly across R4 and R6 respectively. TR4 must be adequately heat-sinked as it dissipates almost 4W even under no-drive conditions. I bolted TR4 through the rear panel to a 1·5 by 2·5in finned heat-sink. Resistors R30–R32 are soldered directly between the emitter of TR4 and the groundplane.

It is important that the vfo coil, L5, be mechanically stable. Ensure that it is wound tightly and fixed rigidly to the pcb; I "sandwiched" the coil between two perspex discs and bolted through the discs to the pcb. Also be sure to use rigid heavy-gauge wire for connecting to C58. I used a 6:1 vernier slow-motion drive which, with the limited tuning range of 100kHz, provides acceptable bandspread; the 0–100 vernier scale (0 = 1·900MHz, 100 = 2·000MHz) gives a surprisingly accurate read-out of frequency, the worst-case error being 1kHz across the tuning range.

The broadband transformers, T1–T4, are wound by twisting together two lengths of 22swg enamelled copper wire. The twisted pair is then either wound on a ferrite toroidal core (T1 and T2), or wound through ferrite double-holed cores (T3 and T4). Identify the start and finish of each winding using an ohmmeter—connect the start of one wire to the finish of the other to form the centre tap (see Figs 5 and 6 for more details). All transformers and the bandpass filter coils were secured to the pcb with adhesive.

I fabricated all of the transceiver, other than the top and bottom panels, by soldering together double-sided pcb materials. It is vital to have a good screen between the pa and the vfo otherwise the transmitter will frequency modulate badly. I used 2in high screens around the pa and vfo areas, and included a screen at the front of the vfo compartment on which to mount C58. If you use lower screens you may need to put a lid over the vfo; cut a tightly-fitting piece of pcb material and bolt it in position to four nuts soldered into the corners of the vfo compartment.

Alignment

Check the pcb thoroughly for correct placement of components and absence of solder "bridges".

Turn the volume control fully counter-clockwise, the TUNE switch to the

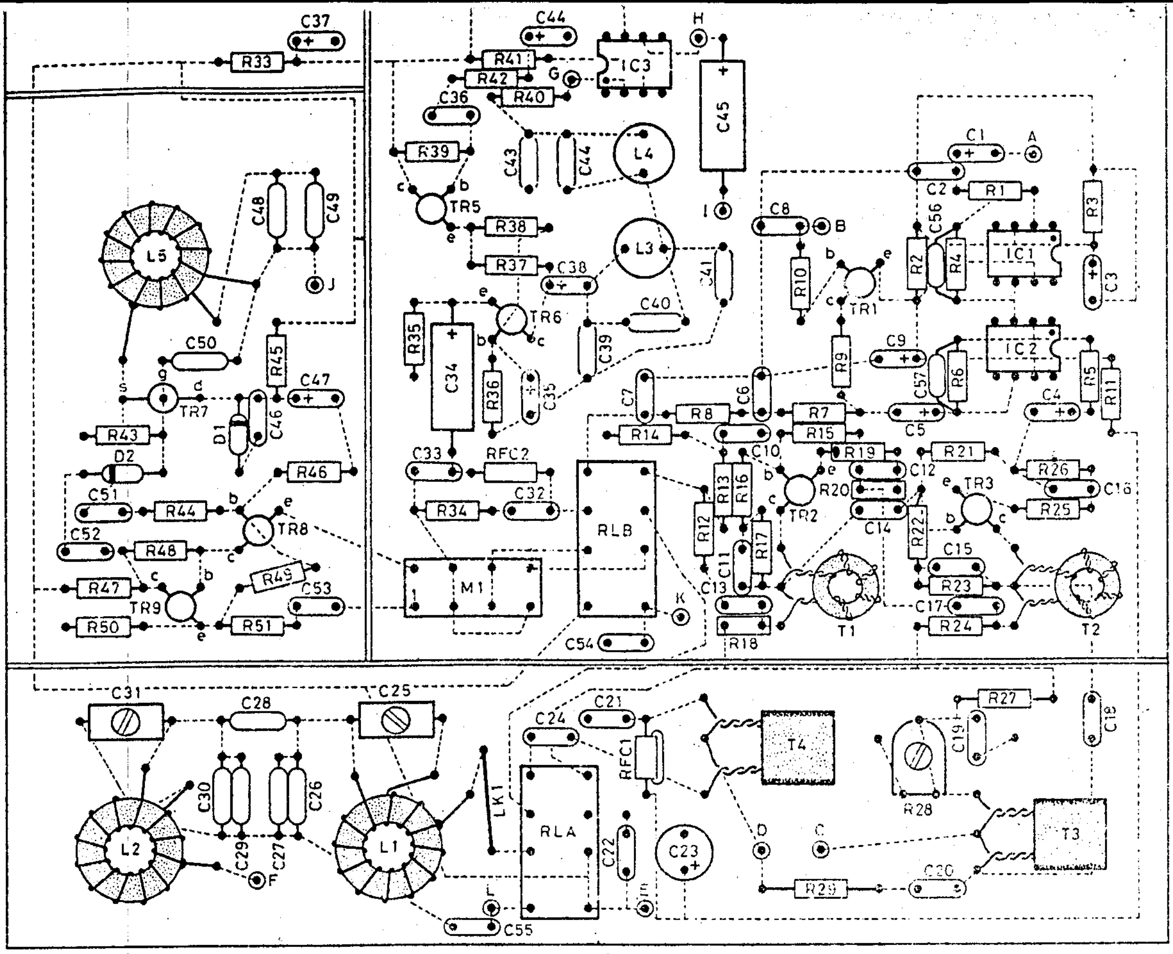


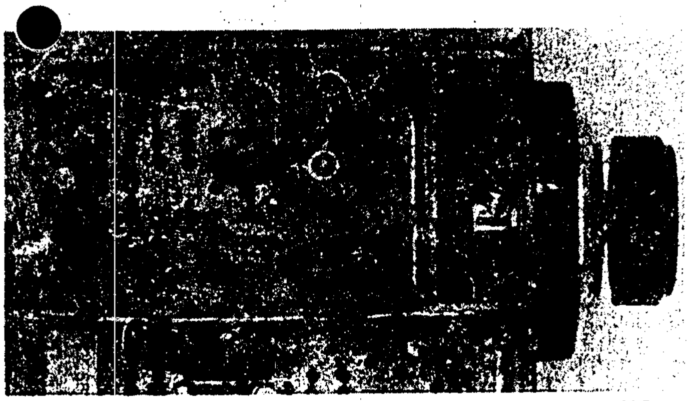
Fig 3. Component layout

off position and R28 fully counter-clockwise. Connect the transceiver to a 12V supply and switch on. Check that the current drawn from the supply is about 50mA.

Check the frequency of the vfo either by using a frequency counter connected to the source of TR7, or by monitoring the vfo on another receiver. With C58 set to mid-position, the frequency should be about 1·95MHz; if it is very different, you can adjust L5 slightly by spreading or squeezing together the turns. Alternatively, major adjustments can be made by substituting alternative values for C49. Check that the range of the vfo is about 1·9 to 2·0MHz.

Plug in a pair of headphones and slowly advance the volume control; you should hear receiver noise (a "hissing" sound). If you have a signal generator, set it to 1 95MHz and connect it to the antenna socket; if not, you will have to connect the transceiver to an antenna and make the next adjustment using an off-air received signal. Tune to a signal at 1·95MHz and alternately adjust C25 and C31 for a peak in its level.

Connect the transceiver to a 50Ω power meter, or through an swr bridge to a 50Ω load. Plug in a low-impedance microphone and operate the ptt switch. Note the current drawn from the supply—it should be about 200mA. Slowly turn R28 clockwise and note that the supply current increases: adjust R28 until the supply current has increased by 330mA. Release the ptt switch and operate the TUNE switch; the power meter should indicate between 1 and 2W.


Detail of top view with C58 removed to show mounting arrangement of L5

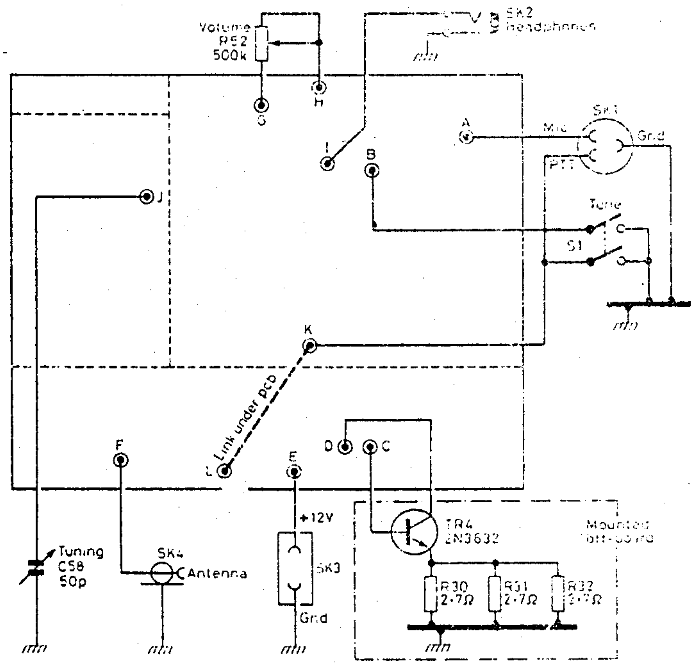


Fig 4. Wiring diagram

Components list

R1, 9, 17, 23, 35	1kΩ
R2, 3, 41, 42	22kΩ
R4,6	47kΩ
R5	4·7kΩ
R7, 8	100Ω
R10, 36, 44	10kΩ
R11, 33	22Ω
R12, 14	150Ω
R13	39Ω
R15, 29	560Ω
R16, 50	270Ω
R18, 19, 24, 25, 47	10Ω
R20	180Ω
R21, 45	330Ω
R22	220Ω
R26	27Ω
R27	330Ω 0·5W
R28	100Ω preset
R30, 31, 32	2·7Ω
R34, 51	47Ω
R37, 40	2·2kΩ
R38, 43	100kΩ
R39	390kΩ
R46	1·5kΩ
R48	820Ω
R49	12kΩ
R52	500kΩ log pot

C1, 3, 5, 35, 36, 38, 44, 47	10μF 16V tant bead
C2, 6, 7, 8, 46, 51, 52, 54, 55	0·01μF ceramic
C4	2·2μF 16V tant bead
C9, 37	47μF 25V tant bead
C10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 32, 53	0·1μF ceramic
C23	100μF 25V elect
C25, 31	60–180pF trimmer (Cirkit 06–18006)
C26, 30	56pF silver mica
C27, 29	680pF silver mica
C28	82pF silver mica
C33	0·33μF
C34, 45	100μF 10V elect
C39, 43	0·068μF
C40	0·033μF
C41	0·1μF polystyrene
C42	8200pF silver mica
C48	330pF silver mica
C49	82pF silver mica
C50	12pF silver mica
C56, 57	0·001μF ceramic
C58	50pF air-spaced variable, SLC law (Maplin FF45Y)

1, 2	37t on T68–2 core tapped at 7t from ground
3, 4	120mH (eg Cirkit 34–12402)
L5	57t on T68–6 core tapped at 14t from ground
RFC1	2t on small ferrite bead
RFC2	47μH choke
T1, 2	10t twisted wire on 10mm od ferrite toroidal core, Al = 1μH/t (eg SEI type MM622). See Fig 5.
T3, 4	4t twisted wire on two 2-hole ferrite cores, Al = 4μH/turn (eg Mullard FX2754). See Fig 6.
TR1	BC179
TR2, 3	2N5109 or 2N3866
TR4	2N3632 (see text)
TR5, 6, 8, 9	BC109C
TR7	2N3819
D1	6·2V 250mW zener
D2	1N914
IC1, 2, 3	741 op-amp
M1	Mini-circuits SBL-1 double-balanced mixer
RLA, B	DPDT 12V relay (eg RS Electromail 346–845)
SK1	Microphone socket
SK2	Headphone socket
SK3	DC power socket (eg Maplin YX34M)
SK4	Antenna socket
S1	DPDT toggle switch

Miscellaneous
Slow-motion drive for C58 (eg Maplin RX40T)
Heat-sink approx 1·5 by 2·5in
Knob for R52

Table 1. Bipolar transistor dc voltages (with 12·2V supply)

	Emitter	Base	Collector	Note
TR1	12·2V	11·6V	11·8V	Tune switch operated
TR2	2·85V	3·6V	12V	Transmit
TR3	1·4V	2·15V	11·6V	Transmit
TR4	0·3V	1V	12·2V	Transmit
TR5	11·2V	11·8V	12·2V	
TR6	0·4V	1V	10·3V	
TR8	0V	0·65V	6·75V	
TR9	6V	6.75V	12V	

Table 2. FET dc voltages (with 12·2V supply)

	Source	Gate	Drain
TR7	0V	0V	6·2V

Table 3. AC voltages

Circuit node	AC voltage	Note
TR7 source	2·6V p/p	1·8MHz rf
TR9 emitter	2·6V p/p	1·8MHz rf
Mic input	4mV p/p	Transmit audio
IC1 pin 6	200mV p/p	Transmit audio
IC2 pin 6	2.2V p/p	Transmit dsb rf
TR2 base	200mV p/p	Transmit dsb rf
TR4 collector	15V p/p	Transmit dsb rf
Ant (50Ω)	30V p/p	Transmit dsb rf

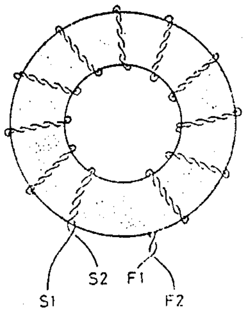


Fig 5. Winding details of T1 and T2. Connect S2 and F1 to form the centre tap. Note that the two wires are twisted together before winding. S1, F1: Start and finish respectively of winding 1. S2, F2: Start and finish respectively of winding 2. Core: 10mm od Ferrite toroid

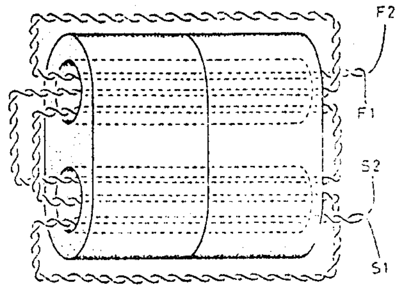


Fig 6. Winding details of T3 and T4. Connect S2 and F1 to form the centre tap. Note that the two wires are twisted together before winding. S1, F1: Start and finish respectively of winding 2. S2, F2: Start and finish respectively of winding 2. Core: Two 2-hole cores stacked end-to-end

At this stage, final adjustments can be made to C25 and C31. Swing the vfo from end to end of its range and note the variation in output power. The desired response is a slight peak in power at either end of the vfo range with a slight dip at mid-range. It should be possible to achieve this by successive adjustments to C25 and C31. For those of you lucky enough to have access to a spectrum analyser and tracking generator, LK1 was included to allow isolation of the bandpass filter.

If you have any problems, refer to Tables 1–3 which show typical ac and dc voltages around the circuit. If necessary, you can tailor the gain of IC2 to suit the sensitivity of your microphone by changing the value of R5.

Final thoughts

In retrospect it would have been useful to have included the lowpass filter (L3, L4, C39–C43) in the transmit audio path in order to further restrict the bandwidth. Normally the roll-off achieved by C57 and C56 combined with the low output power means that you are unlikely to cause problems for adjacent QSOs. However, when using a 200ft vertical antenna during portable operation, the transceiver puts out a potent signal, and a reduction in bandwidth would then be more "neighbourly".

A cw facility could be added fairly easily using the TUNE pin as a keying point. You would need to add rit facilities—probably by placing a varactor diode between TR7 source and ground. You might also consider changing to a bandpass audio filter rather than a lowpass audio filter in the receiver.

The transceiver can be adapted for other bands by changing the vfo components and the bandpass filter components—all other circuitry is broadband. You will need to worry more about vfo stability as you increase frequency, and you may find that the gain of the vfo buffer falls—you can overcome this by decreasing the value of R44. The noise figure of the receiver is adequate for operation on the lower frequency bands but on 14MHz and above you will probably need a preamplifer. Those who enjoy experimentation might try changing the vfo to a vcxo, adding a preamplifier to the receiver, and seeing if operation on 50MHz is possible!

Finally, it has been interesting to note that, despite theory, with careful tuning it is quite possible to resolve dsb signals on the direct-conversion receiver.

Reference

(1) "Wideband linear amplifier", J A Koehler, VE5FP. *Ham Radio* January 1976.

Daka Electronic Developments

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Phone 011-976-4041 evenings.

QRP HF Transceiver

Notes on components supplied.

1) Electrolytic capacitors may be supplied in place of some or all tantalum.

2) C58 is NOT supplied. You may use the low capacity section of a transistor radio MW / FM tuner capacitor.

3) L3 and L4 may be 100 mH and marked 104.

4) TR1 is a BC307.

5) TR2 and TR3 are BFY51.

6) TR4 will be an RCA device. The connections are :-

7) TR7 connections are :-

8) M1 can be a SBL1 or SRA1 mixer.

RELAY connections.

If the relays supplied in the kit are manufactured by Siemens please note the following.

It has been brought to our attention that the relay used in the kit is polorised as far as the voltage applied to the coil is concerned. The printed circuit board needs altering to suit this near relay B.

Carefully cut the track on the connections going to the relay coil (near C54) and swop them over. The pin nearest to the connector marked "K" should go to posetive.

Operation on a different band.

The kit has all parts supplied for operation on the 1.8 MHz band as per the original article. A number of customers have used this design on 40 m with great success. To ensure the kit tunes up on 40m change the coils as follows :-

L1, L2, L5 wind with about 20 turns on the red torroids. L1 and L2 shold be tapped at 5 turns from the earthy end. The transmitter amplifier stages are all wide band and do not require any changes.