The 220 MHz All-Mode Transverter

Designed for the dedicated home-brewer.

by Robert E. Bloom W6YUY

Because of the increased interest and activity in 220 MHz single sideband and the positive response to my Two-Meter Transverter project in July 1987 *73* (pps 32–43), I have now designed an improved, 220 MHz version of the transverter. This transverter is capable of FM repeater operation as well as CW and SSB, and it's much more sophisticated than the usual FM transceivers and hand-helds on the market. All frequencies on this unit can be set with direct read-out to the nearest 10 Hz. Of course, DX simplex operation on both FM and SSB is one of its most exciting features.

Like the earlier unit, this is an all-mode transverter specifically designed to interface with the Kenwood TS-940S HF transceiver. It will also work with other full-frequency coverage transceivers equipped with a transverter access plug. The transverter has a CW output of 3-½ watts. I will cover in a later article a 220 MHz DMOS linear amplifier with a power output of 60 watts.

Why Not PC Cards?

The construction of this unit uses point-to-point wiring in a soldered PC-card structure that provides several benefits.

1. A printed circuit board would require foil circuits on both sides, making double-deck construction impossible.
2. Compartmentalizing would require a separate PC board for each stage or section.
3. A PC card would require more space because of restrictions on parts placement. With this type of construction you can use the walls of the compartment as well as the floor for mounting parts.
4. Exact duplication of components is not required.
5. Excellent interstage isolation.
6. More freedom and ease of modification than normal printed circuit board techniques.

Your TS-940 transceiver must be modified, of course, to work with the 220 MHz transverter, because 222 to 225 MHz will be mapped into 22 to 25 MHz and the unmodified transceiver will not transmit outside the ham bands. (Obviously, it is not legal to transmit with the modified Kenwood outside the amateur bands authorized by your class of license.)

Take It Step-by-Step

Realizing the apprehension you may feel when looking at a complex project, I provided, in Figures 5 and 6, drawings of the layout of the major parts. By showing the approximate placement of coils, tuning capacitors, and transistors, I hope to simplify the placement of the rest of the components for you. Since you are building this unit step-by-step, you won't have to place the shields between stages in exactly the locations shown in the drawings. Also, your components may be of different sizes, but the compartments should have enough space in most cases.

THE HOUSING

Case and Module Fabrication

The 220 MHz transverter is a one-piece module with a housing made up of double-sided PC board material. The top of the chassis contains the receiver and oscillator chain; the bottom has the transmitter and control circuitry.

The outside dimensions of the transverter assembly are 8-⅝ x 4-¼ x 2-⅜″. The height of the partitions is 1/16″ less than the depth of the compartment, so the top and bottom covers fit flush with the side panels. Similarly, the front and back panels are ⅛″ wider than

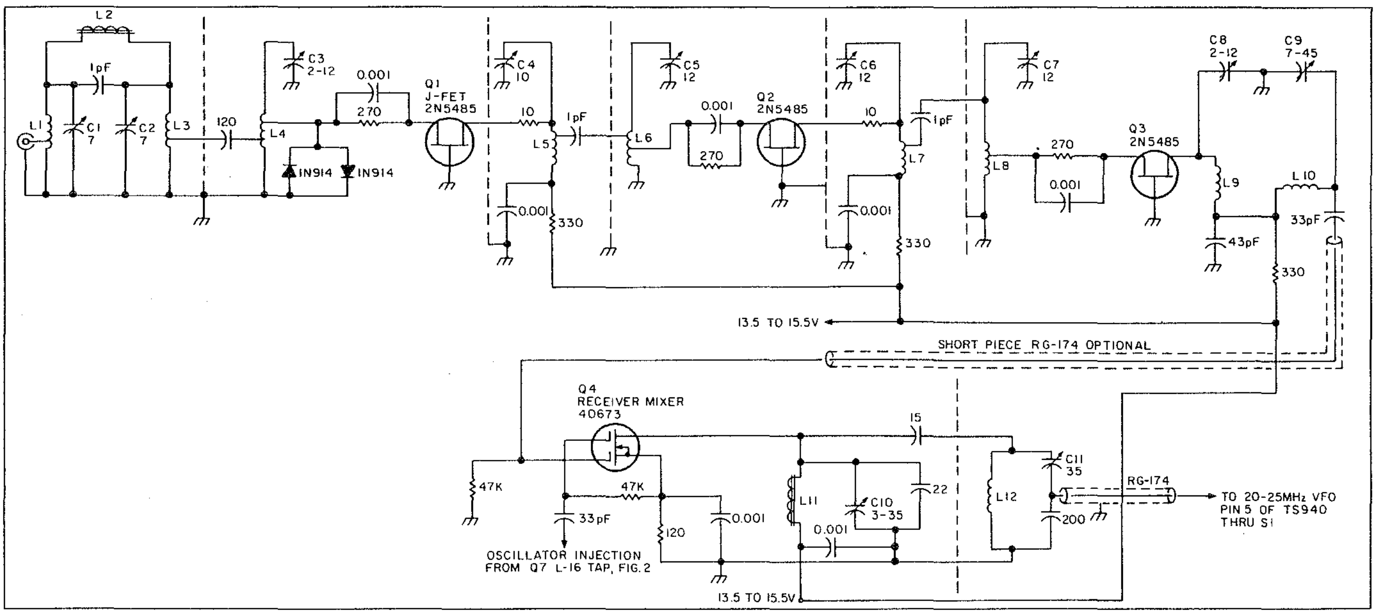

Figure 1. Schematic of the receiver portion of the 222–225 MHz transverter.

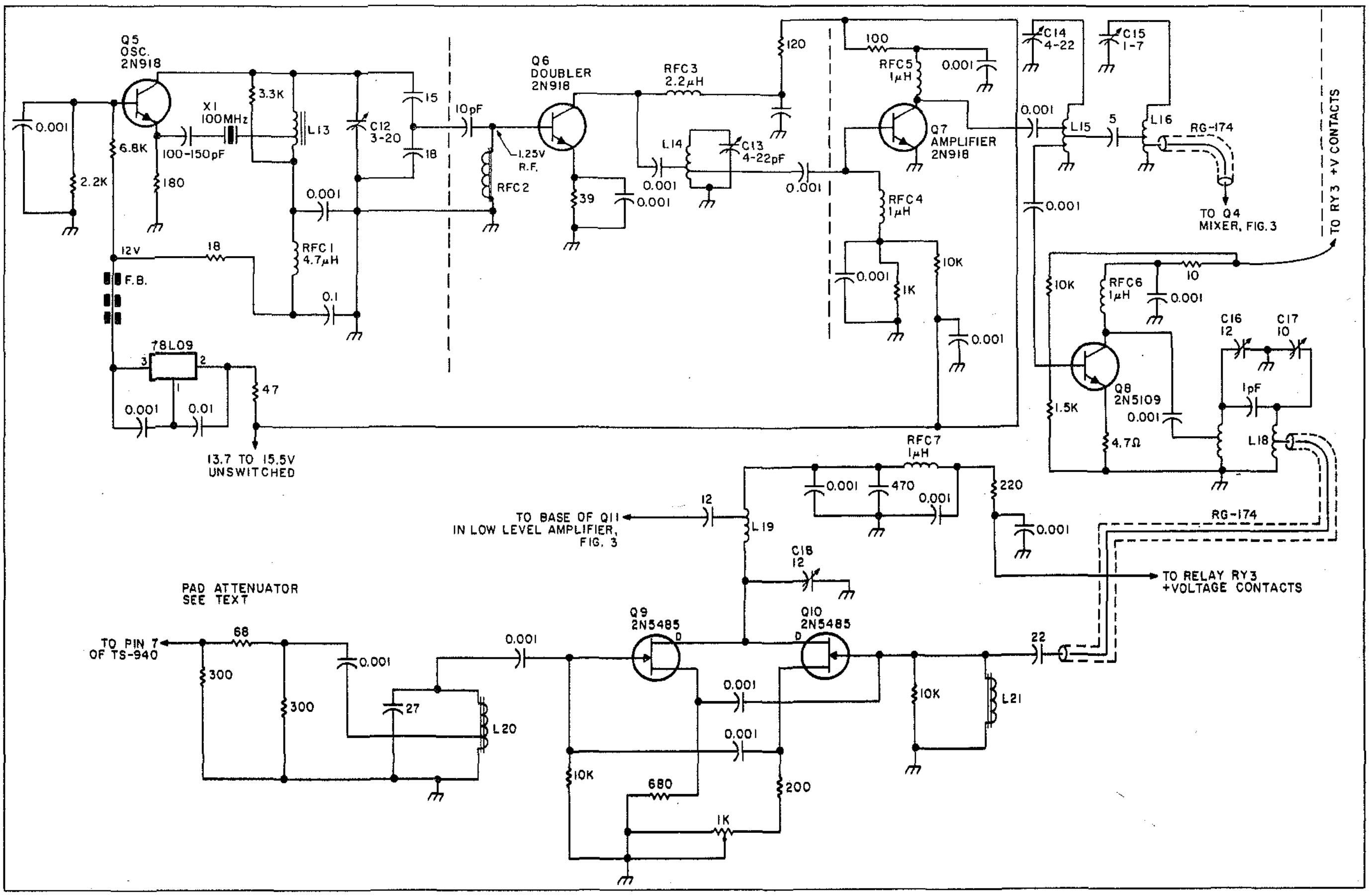

Figure 2. Schematic of crystal oscillator circuit (100 MHz) and doubler.

the main circuit board chassis to allow for the 1/16″ side panel thickness.

Draw a pencil line down the middle of each side piece to help in locating the main center board that separates the top from the bottom. Start by tack-soldering just inside each end, making sure that the sides are at exact right angles with the center board. Then tack the end pieces into position. When the box is square, solder the corners and then seam-solder the sides from the inside.

Figures 5 and 6 are parts layout drawings showing the individual compartment sizes, ±1/16″ and do not allow for the ±1/16″ thickness of the separators. These dimensions are flexible and can be used as an indication of how much room you need and how much space you have left as you go along.

The compartment separators are also made up of double-sided PC card stock and construction is serial: you complete one stage and install a separator before going on to the next stage. This way, you won't be caught either short or long on space. Drill all feedthrough holes in the compartment separators before soldering the separators in—drilling afterwards is difficult!

Single-sided PC stock is used for the terminal mounting pads to which component leads are soldered. If all the PC material you have is double-sided, you can remove the foil from one side by holding the material in a bench vise, heating one side gently with a propane torch, and pulling off the foil with pliers.

Make up a supply of single-sided strips—⅛″, 5/32″, and ⅜″ wide—and snip off pieces as needed with diagonal cutters. Using a single drop of Eastman 910 cement (Crazy Glue), position these pads where needed with long-nose pliers. Four seconds later, you can solder to the pad. Should you decide that the pad is not in exactly the right position, you can remove it by prying with a pocket knife or small sharp screwdriver. Do not re-use a pad, as it will not hold securely the second time.

The unit will operate well without the covers in place. However, when the top cover is removed exposing the receiver's pre-selector stages, the unit will pick up strong signals even if it isn't connected to an antenna. Rather than secure the covers permanently, you can hold them in place with transparent tape for easy access to the circuitry.

Panel Hardware

You can drill the holes in the front and back of the case either before or after the box is

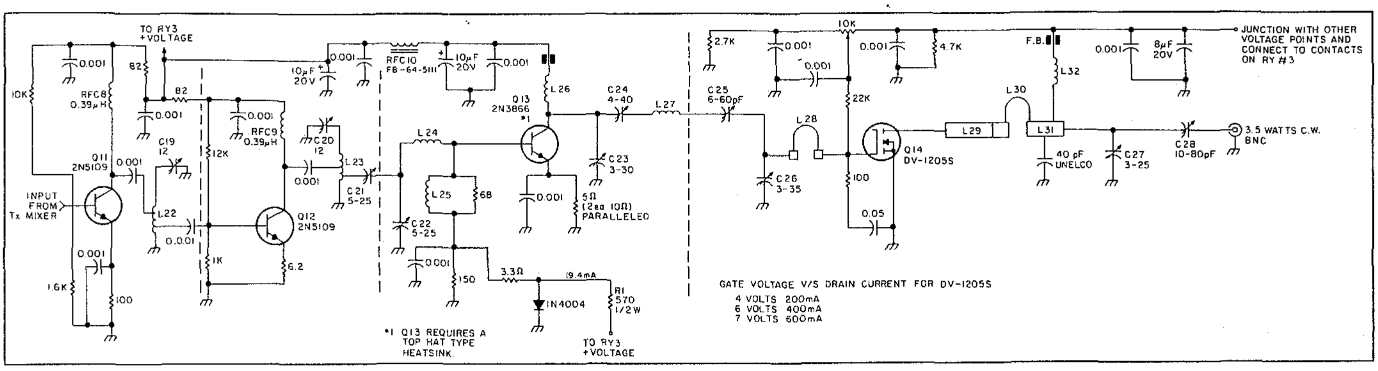

Figure 3. 220 MHz transmitter low-level amplifier section.

220 MHz Receiver
Major Components Parts List and Coil Data
(Small resistors, capacitors, and inductors not listed)

C-1, C-2	1–7-pF quality miniature piston capacitors
C-3–C-8	2–12 pF Johnson air variable, PC board ceramic
C-9–C-12	3–35 pF ceramic variables
L-1, L-3	Four turns #16 or 18 tinned wire ¼″ inside dia., tapped at 1-¼ turns
L-2	19 turns #20 enameled wire on T-50-12 Amidon core, or 21 turns #24 enameled wire on T-37-12 core
L-4–L-9	4 turns #16 tinned wire, wound on #3 drill (0.212″), all four turns spaced 1-½ wire diameters
L-4	tapped at ¾ and 2-½ turns
L-5	tapped at 2 turns
L-6	tapped at ½ and 3 turns
L-7	tapped at 2-½ turns
L-8	tapped at 3 turns
L-9	no taps
L-10	tapped at 3 turns
L-11	22 turns #28 enamel wire on T-25-6 Amidon powdered-iron toroid core
L-12	Same as L-11 but 19 turns
FB Ferrite Beads	101 size of 43, 64, or 75 material; typical Amidon designation, FB-43-101
Q-1–Q-3	2N5485 or 2N5486 (or equivalent) JFETs
Q-4	40673 or 40673A dual gate MOSFET
Q-5–Q-7	2N918 transistor
Q-8	2N5109
Q-9, Q-10	2N5485 or 2N5486 JFETs

Note: All resistors used in the project are ¼ watt ±10% unless stated otherwise.

Table 1.

assembled. The front panel has two BNC bulkhead connectors on the left edge. One is for received signal in and the other is for transmitted signal out, to interface with the power amplifier. An LED shows when power is applied. The three-pole, double-throw miniature switch and eight-pin male mike bulkhead connector complete the panel. The eight-pin connector couples to the TS-940 interfacing cable. The back panel has a four-section miniature barrier strip for source power to the transverter.

CIRCUIT SECTIONS

Receiver Converter

The receiver portion (shown in Figure 1) has three JFET pre-amplifier stages. Dual gate MOSFETs would provide twice the gain, but much less stability and more noise. The bandwidth of these stages is set by positioning the taps on the RF coils (see the Coil Tapping sidebar). A tap placed closest to the top or high impedance point of the coil provides heavy loading, driving the Q of the stage down for a broader bandwidth. The lower the tap point, the higher the circuit Q, and the more selectivity and gain per stage.

Because the transverter is not retuned during operation, the bandwidth or bandpass discussed here is the total bandwidth over which the transverter will work. The actual operational selectivity is provided by the TS-940 being used as a tunable IF.

Each of these stages provides about 12 dB of gain, with 15 dB the maximum. A bandpass and image frequency rejection filter precedes the preamplifier.

Crystal Oscillator

The oscillator is a variation of the Butler design—one of my favorites. The oscillator circuit is particularly suited for overtone crystals, and, with light loading, is very stable.

The oscillator coil L-13 in Figure 2 is tuned by a network of fixed and variable capacitors. The variable capacitor is tuned for resonance, while the parallel and series divider provides the required drive level to the frequency doubler. (With the proper selection of capacitors, we can retain the correct parallel [product-over-the-sum] capacity, and we can select a correct drive level for the frequency doubler. In addition, we reduce loading on the oscillator output circuit.)

The selection of coil tap on L-13 provides the oscillator feedback voltage required for stable oscillation. The 100 MHz crystal oscillator feeds the doubler, which retains about 66% of the oscillator's energy. Using a 100-MHz crystal and a doubler, the 200 MHz is much cleaner than it would be if you used a tripler. A simple doubler circuit provides the required 200-MHz output frequency, while the amplifiers with double-tuned bandpass circuits clean up the frequency from the output of the doubler stage.

To further clean up the 200 MHz signal before it enters the receiver mixer, we add a third amplifier and bandpass filter stage. A fourth, and similar amplifier stage provides the heavier signal required for the transmitter mixer. The double-tuned bandpass filters in these amplifier stages clean up whatever garbage is generated in the early stages of the oscillator chain.

Transmitter Mixer

Much research went into the determination of transmitter mixer circuitry. Both active and passive, double- and single-balanced types were studied. I selected the single-balanced, active JFET circuit after comparing major characteristics such as dynamic range, suppression of intermodulation products, and cross-modulation effects. FETs were selected over bipolar transistors for their inherent transfer characteristics approaching a square law response, thus providing a reduction of third overtone products. Harmonic distortion and cross-modulation effects are third-order dependent, and are greatly reduced when using FETs in a balanced mixer.

For RF amplification, use the following guide to set up the DV-1205S V-MOSFET stage Q-14 in the main transverter unit (see Figure 3). The level of drain current and ultimate power output of the stage is a function of gate voltage controlled by the 10k potentiometer. Four volts gives a drain current of 200 mA, six volts yields 400 mA, and seven volts sets up 600 mA. If you don't get an increase in power output with increased drain current, you don't have enough drive power and it isn't economical to increase the drain current further. Since this project has three MOSFET linear amplifier stages, set the output levels for only what you require. On the other hand, if the drive is much greater than you need, don't worry about blowing the FETs, since you cannot hurt them by overdriving.

Control Circuit Function

Refer to Figure 4 and Table 4. Plugging the DIN plug into the TS-940 mechanically switches the TS-940's input circuitry to desensitize it to HF signals. At the same time,

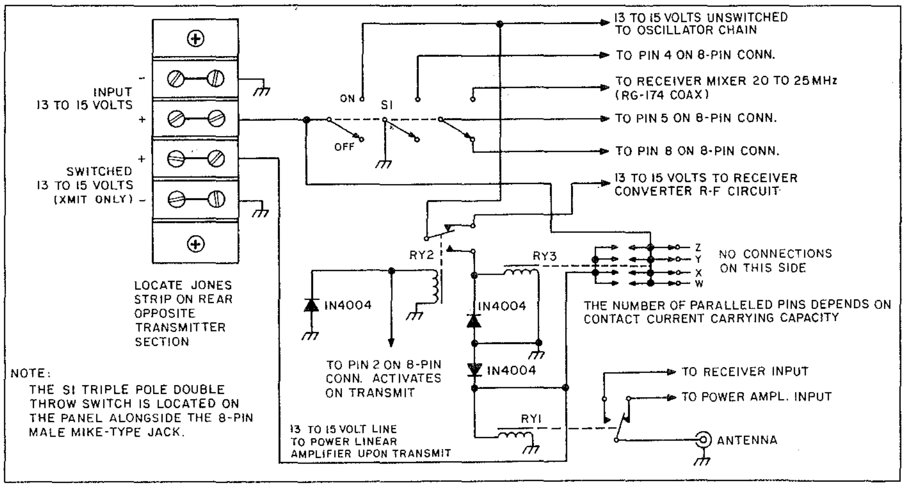

Figure 4. Control circuit wiring diagram.

With SW-1 ON, the first set of switch contacts applies 13 to 15 volts from the input terminals of the barrier strip to the RY-2 armature contact, providing voltage to all of the receiver circuitry and the oscillator chain (except for the Q-9 stage). The second set of switch contacts grounds the coil of RY-3 in the TS-940S, closing the relay, disconnecting the VFO, and disabling other LF circuits in the TS-940.

When you press the microphone push-to-talk (PTT) switch, the Kenwood puts 12 volts at 50 mA on pin 2 of the 940's DIN plug, activating the transverter RY-2, which in turn removes the supply voltage from the receiver and activates transverter RY-3. RY-3 then applies supply voltage to the Q-9 output stage along with all the source voltages to the transmitter section. In addition, plus voltage is supplied to the barrier strip for the outboard linear amplifier and antenna relay #1. Releasing the PTT switches the transmitter and its associated circuitry off, and returns the unit to receive.

Toggling SW-1 to OFF, the arm of the third pole connects pin 5 with pin 8 on the 940's transverter plug. This allows the TS-940 to operate in the normal manner on HF, even though the transverter is still connected.

When purchasing the RY-2 control relay, keep in mind that its 12-volt actuating voltage comes from the TS-940, and the maximum current available is 50 mA. Many 12-volt relays require more than twice this level. The unit you select should have a field coil resistance of *no less than* 250 ohms.

TS-940

TS-940 Interface Cable

A 30″ cable connects the transverter to the XVTR plug on the back of the TS-940 (see Table 4). Get the eight-pin DIN plug from Kenwood. Don't try to buy this plug elsewhere, as the plug you get probably won't fit the Kenwood's jack. I purchased three from other sources; no two were the same and none of them fit the TS-940. Just connect like numbers on the DIN plug and the eight-pin mike jack. You'll need three runs of small-diameter coax for pins 5, 7, and 8. Use cable with a Teflon dielectric. Don't use RG-174—the dielectric can melt during soldering, causing a short. Pins 1 and 3 are shield ground. Use a good grade of #20-stranded between the two number 2 pins and the two number 4 pins. Pin 6, ALC on the transceiver, is not used. Pin 6, by the way, is the center pin on the DIN plug, while pin 8 is the center pin on the eight-pin mike connector...

Recall that the very act of inserting the DIN plug into the 940 transverter jack disconnects the HF front end in the 940 to avoid leak-through of HF signals at what is now the first intermediate frequency. In order to use the Kenwood on HF when the transverter is plugged in, a switch in the transverter connects pins 5 and 8 when the transverter is turned off.

Pin 2 provides 12 volts (at a maximum of 50 mA) during transmit for use as PTT in the transverter. A ground on pin 4 by the transverter disables the TS-940's power amplifier. RF/IF input signals between 22 and 25 MHz come from the transverter to the Kenwood on pin 5 with the outgoing (transmitted) signal at a level of about 100 mW on pin 7. Pin 8 is the TS-940's HF input, which must be connected to restore HF operation.

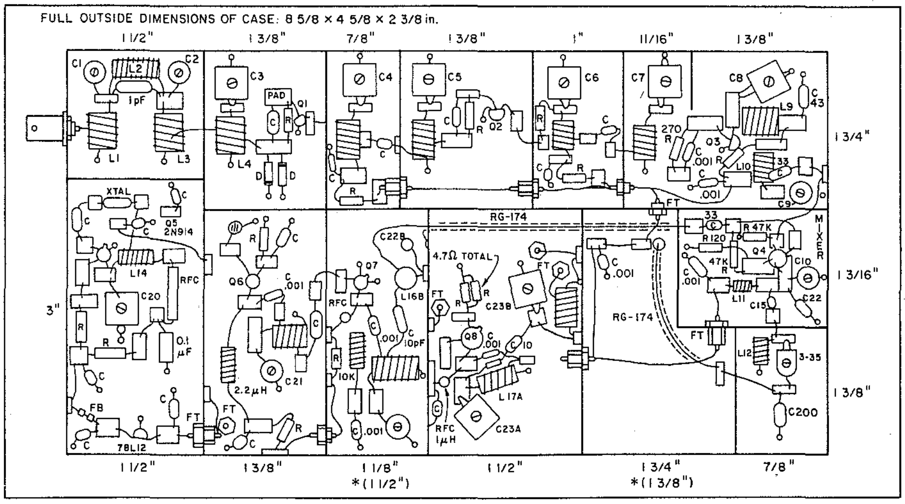

Figure 5. Major parts positioning (approximate dimensions) for the receiver and oscillator, top section.

TS-940 Modification

To enable the TS-940 to transmit outside the regular ham bands, cut diode D-130 from the circuit. The transceiver will then transmit anywhere between 1500 kHz and 30 MHz. D-130 is located on the unit "B" PC board just behind the LCD display on the panel. (The diode is identified, as are other components, by screening on the PC board.) I removed the five screws on the module containing the board, but the board is still difficult to access and requires patience. A letter from a New Zealand reader of my previous transverter article suggested loosening the panel to the point where it could be tilted forward, exposing the diode, which is then cut free at one end using a diagonal cutter. The VFO frequency for the tunable IF is 22 to 25 MHz. Thus, the TS-940 dial read-out for a frequency of 223.259.81 MHz will be 23.259.81. The first digit "2" is understood, as all of the frequencies are in the 200-MHz range. For example, 22 on the dial indicates 222 MHz, plus all of the subsequent digits. Note that the frequency is read to the closest 10 Hz, so be sure to zero-beat both the TS-940 crystal and the transverter oscillator to WWV.

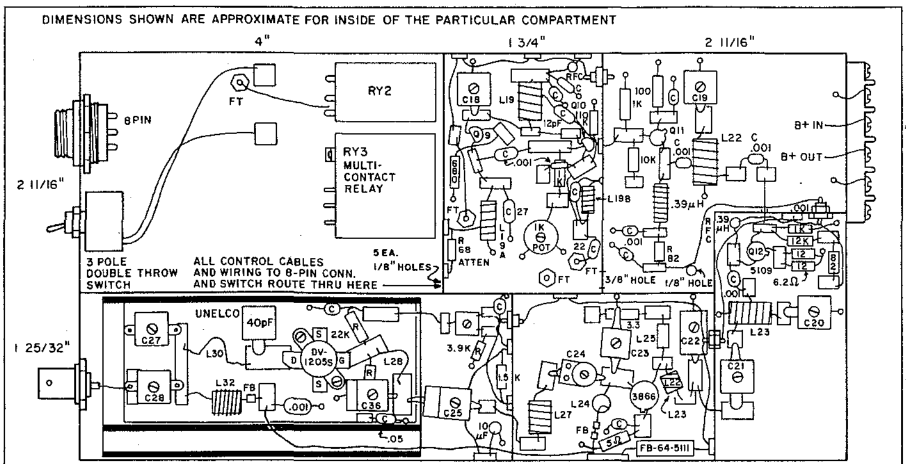

Figure 6. Major parts positioning for the transmitter and control, bottom side.

Construction Aids

Figure 4 shows the control circuit wiring diagram. Schematics for the receiver and transmitter sections, as well as separate major parts list for each section, are furnished. See Tables 1–3. In addition, see the photographs of both top and bottom views of the transverter.

If you follow the coil winding data, you should not have a problem attaining resonance in any of the stages. Coil construction has been further simplified by using toroidal cores. These are readily available in small quantities at under a dollar each from *Amidon Associates, Inc., 12033 Otsego St., North Hollywood CA 91607.* Tell them you saw the cores mentioned in *73 Magazine.*

Potpourri of Technical Construction Notes

In the bandpass filter in the Q-4 transistor stages, L-10 is lightly coupled and at right

220 MHz Oscillator Chain and Transmitter Mixer Major Components Parts List

C-12	3–20 pF miniature air variable or ceramic disk
C-13, C-14	4–22 pF miniature air variable or ceramic C-151-7 pF piston capacitor
C-16, C-18	2–12 pF Johnson air variable used on PC boards
C-17	2–10 pF Johnson similar to C-16
RFC-1	4.7 µH
RFC-2	3 turns on FB-64-5111 6-hole Amidon ferrite core
RFC-3	2.2 µH
RFC-4–7	1.0 µH approx. 25 turns of #28 enameled wire on a ½-watt resistor form
L-13	7 turns #20 enameled wire tapped at 2 turns from cold end, wound on a T-37-12 powdered-iron Amidon toroid core
L-14	4 turns #18 bus wire 3/16″ inside dia., 9/16″ long, tapped at ¾ turn at 3-¾″ from cold end
L-15	5 turns #18 bus wire 3/16″ ID x ½″ tapped at 1-½, 2½ at 4 turns
L-16	6 turns #20 tapped at ¾ at 5 turns
L-17	5 turns #18 bus wire ¼″ x ½″ tapped at 1-½ turns
L-18	4 turns #18 bus wire ¼″ x ½″ tapped at 1-½ turns
L-19	4 turns #16 bus wire wound on #3 drill (0.212″) tapped at 1-½ turns from cold end

Table 2.

angles to the center of L-9. Do not place L-9 and L-10 closer than ¼″ to each other. The bandpass filters of both the Q-7 and Q-8 circuits also have their coils at right angles for minimum coupling. Here, the coupled coils should be placed at least 1″ apart, so that coupling is primarily through the 5 pF and 1 pF capacitors, respectively. Even at this distance, there's some mutual coupling.

There are a number of places where RF chokes are called out. Most of these are wound using ¼- and ½-watt resistors as the coil forms. The following should assist in coil winding.

A reactance vs. frequency, capacity, and inductance chart or a cardboard reactance slide rule are great tools. A grid dip meter is another. You'll need several 0.39-µH chokes. A 0.39-µH choke will resonate at 50 MHz when shunted with a 27-pF capacitor. By using this point, you can locate other capacitance and inductance values on the scales. You can make the 0.39-µH unit with a ½-watt resistor of 3000 ohms or more. Make notches at the ends of the resistor with a jeweler's file to prevent the wire from slipping. Close-wind 25 turns of #28-gage enameled wire on the resistor, and grid-dip with a capacitor to check the value.

You'll also need some 1.0-µH chokes. These should resonate at 16 MHz when shunted with 100 pF. Fill a ½-watt resistor with #31 wire. Wire size is important. Note that 25 turns of #28 wire on a ½-watt form also makes the same 1-µH value. As an additional aid, note that a value of 0.18 µH resonates at 70 MHz when shunted with 27 pF.

Refer to the dimensions of stage components. Notice that on the receiver side, a compartment of 1¾″ has only a few components. This compartment originally had a redundant stage. Notice also that the Q-7 stage is a bit crowded. If you expand the width of this compartment, you will be able to move the Q-8 stage down.

On the front panel, the BNC connectors are located 1″ in from the case edge and are 1-¼″ on center from one another. The eight-pin mike-type connector is ⅞″ in from the opposite edge of the case. Positioning of these parts is not critical.

I had no problem laying out the complicated transmitter section. If you need more width, the Q-12 adjacent stage has plenty of room and can be moved further to the right.

A number of relatively long conductor and RG-174 (⅛″ coaxial cable) runs enter and leave compartments that are not adjacent, but opposing. Also, some of the feedthrough terminals are *not* bypass capacitor feedthroughs. These also come out on the opposite side of the box (top or bottom). Carefully check to make sure that there is nothing in the way on the opposite side, and that the feedthrough enters the proper stage on that side. The component layout drawings represent relative positioning. In order to keep the drawing clear, only major components have been drawn in.

Caution: The Q-13 2N3866 transistor requires a top-hat heat sink. The case of this transistor is connected to the collector and it takes unkindly to being shorted, even for an instant. *Make sure the top hat clears other parts when positioning this transistor on the board.*

Test Equipment

In order to test and align your transverter, you will need the following test equipment.

1. A stable signal generator or calibrated oscillator and adjustable 50 ohm attenuator covering the appropriate RF range.
2. An electronic frequency counter covering the appropriate frequency range.
3. A VHF range RF vacuum tube voltmeter or a good DC VTVM with UHF RF probe. (Solid state is fine, too.)
4. A VHF grid dip meter to check coil resonance. (Not absolutely necessary if you follow coil winding data closely, but a real aid.)
5. A capacity bridge to confirm small values of capacity marked, and to set a given capacity in a test circuit. (See *Ham Radio*, March 1980, page 54.)
6. A Bird Model 43 wattmeter or other power measuring device, and a 50 ohm load (termination).
7. A multi-range Volt-Ohm milliammeter.

220 MHz Unit RF Chain Major Parts List for Transmitter

C-19, C-20	2–12 pF Johnson air variable for PC boards
C-21–C-23	5–25 pF Arco 400 series compression
C-26, C-27	5–35 pF Arco 400 series compression
C-24	4–40 pF Arco 400 series compression
C-25	6–60 pF Arco 400 series compression
C-28	10–80 pF Arco 400 series compression
Q-11, Q-12	2N5109 transistor
Q-13	2N3866 transistor with top-hat heat sink
Q-14	M/A COM PHI RF power MOSFET DV-1205S 5 watt
L-22	5 turns #18 bus wire, wound on #3 drill, 9/16″ long, tapped at ½ and 1-½ from cold end
L-23	Same as L-22, tapped at ½ and 1-⅝ turns
L-24	3 turns #18, 0.3″ diameter spaced 2 wire diameters
L-25	7 turns #28 wound on a 62 or 68 ohm ¼ watt resistor
L-26	5 turns #18 bus wire on #3 drill, 9/16″ long
L-27	3 turns #18 bus wire on #3 drill, spaced 3 wire diameters L-28, L-30¾″ of #16 tinned bus wire bent into a hairpin ⅓″ diameter
L-32	8 turns #22 Teflon covered wire, close wound ¼″ diameter
L-29	¼″ wide strip of single-sided PC board material, epoxied as though it were another pad 0.66″ long
L-31	As in L-29, but ½″ long
R-1	Part of Q-18, 2N3866 bias circuit 570 ohm, made of a 1k ohm and 1.3k ohm ¼-watt resistors paralleled

Table 3.

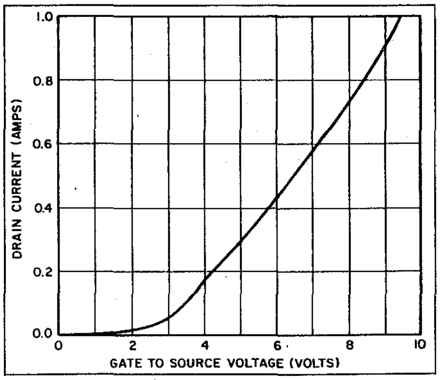

Figure 7. Drain current vs. gate-to-source voltage for the DV-1205S, located in the low-level amp section.

Where To Find Components at Reasonable Prices

In this project you will use quantities of miniature plate capacitors, various sizes of compression capacitors, disc ceramic variables and fixed capacitors, and dipped silver micas (dog bone) components. Fixed disc ceramic of 0.001 mF are sprayed around the source voltage lines as bypasses and as both coupling and decoupling circuits. In circuits requiring a degree of stability, use silver mica. Miniature PC board air variables, Johnson 2–12 pF, usually 8 plates total, are used in stable RF circuits. These plates and small, high quality Arco compression type resonate coils.

You will notice lots of tuning capacitors. This adds up to a nice piece of change. Many of the stages in the receiver could be tuned temporarily with a good-quality variable capacitor. Remove the variable carefully so as not to change its setting and measure its value with a capacitance bridge. Now insert a dipped silver-mica of that value in that spot. You can make minor adjustments by compressing or expanding the coils on the toroidal core until resonance is re-established. This is a mildly complex substitution I have seen described in many publications.

All powdered iron and ferrite toroidal cores and baluns are available from Amidon Associates. You can buy the eight-pin DIN plug from Kenwood. Get two. The price ranges from $2 to $2.50 each. I purchased my crystal from *Jan Crystals, 2400 Crystal Drive, Fort Myers, Florida 33906-9989.* Order series resonant 0.001 percent accuracy and enclose a schematic diagram of the oscillator circuit.

MHz Electronics Inc., 3802 N. 27th Ave., Phoenix, AZ 85017 advertises in most ham publications. They also have crystals, transistors, and Unelco noninductive capacitors for the power amplifier. (Send for a catalog.)

Another excellent source for dipped silver mica capacitors, miniature variables, JFETs (15¢), 4067 (25¢) relays, and the small heat sink 2N3866 is *Hosfelt Electronics, Inc., 2610 Sunset Blvd., Steubenville, OH 43952.* The eight-pin mike type plug and jack are available from *Henry Radio* and *Radio Shack.*

Parts are also available at ham swap meets, and I have some items at very reasonable prices. If you have questions or comments, feel free to write me. Enclose an SASE for a response. Upon completing this project (I wish to emphasize taking your time, step by step), the gratification and pride you will feel cannot be expressed on paper.

The 220 power amplifier will appear in a subsequent issue of *73 Magazine.*

Coil Tap Mystery

Many hams throw up their hands when it comes to determining the position of a tap on a coil. In many cases, the tap impedance must match that of the following stage. Many hams who understand why the tap is there, think, "That's fine. I can find the proper point if only I know the base impedance of the transistor, or the collector impedance." Mathematical analysis can dissuade almost anyone, but don't despair!—several aids are available.

The impedance Nomogram, found in most handbooks, is practically indispensable for the RF builder. Better still are the cardboard reactance slide rules usually found in technical book stores.

AC or RF calculations are more complex. For example, you might want a capacitor coupling for an RF circuit, but you don't know which size capacitor to use. You can determine the size by relating the capacitor resistance to DC. Here the slide rule or Nomograph comes in handy. Since you know the frequency and you know what would be a tolerable resistance, you can line up the arrow with the frequency and look at the resistance scale adjacent to the capacitance scale. Select the capacitance that is opposite the lowest resistance you want.

We call the AC resistance "reactance" or "impedance." In a resonant circuit, to find a coil impedance, take the value of the capacitance that resonates with this circuit, set the rule to this frequency, and look up the reactance. In a circuit at resonance, the inductive and capacitive reactances are equal.

Often, instead of a tapped coil, you will find a capacitive divider across the coil with the tap at the junction of the two capacitors. The total capacitance of two capacitors in series can be compared to two resistors in parallel (the product of each over the sum of each):

$$C_{ST} = \frac{C_1 \times C_2}{C_1 + C_2}$$

After you get the resultant capacitance, use the slide rule to determine the reactance. You can find the reactance of each of the capacitors individually. See them as two resistors in a series across the coil, and you can visualize the proportions of voltage across the two resistors, i.e., frequency is 25 MHz. Two capacitors of 62 pF in series are across the coil. The reactance of the capacitors at that frequency is 100 ohms. The tap is at the 50 ohm point of the coil. Do not confuse this as the center of the coil, as the inductive reactance across the coil follows a square law rather than a linear law. The reactance of the coil at this point is ¼ of the total.

Coil Tap Loading

This is the meat of coil tapping! You might wish to make some changes in the bandwidth of the receiver section of your transverter. Possibly, if you are interested in only a portion of the band, you may want to sharpen the selectivity.

Occasionally, when tuning a capacitor for resonance, you find a really sharp peak. Another time you might find the capacitor to have a much broader peak. Why is this? You have seen resonant curves in handbooks. If the circuit Q is high, the curve will have steep sides and a narrow bandwidth at some point down the curve, usually the half power point (3 dB). Measure the frequency at the half-power point on the low frequency side of the peak and again on the high-frequency side. The difference in frequency will be the bandwidth. If the coil Q is low, the bandwidth will be greater than if the Q is high.

How do you vary Q by tapping the coil? We can assume that in this circuit (a receiver RF amplifier stage) you don't know the collector impedance or the base impedance of the following stage. But you do know that there will be two taps on the coil, and that the taps will affect its Q and thus its selectivity or bandwidth. Here you have a coil and capacitor which will resonate this circuit at the desired frequency. If the coil wire is sufficiently large, and the coil diameter is ⅓ to ½, the length of the coil, the circuit should have a high Q called "unloaded Q." The selectivity will be high and the bandwidth will be very narrow.

Now you have to get this combination into the circuit to do some work. Ground one side of the coil to make the low impedance point. You want to feed energy into the coil from the collector of the transistor of that stage. The collector impedance will load the Q of this coil. If the impedance is high, you can connect it to the high end of the coil. The ideal point is where the Q drops to one-half. Though the ideal is not always possible, at any rate the bandwidth will increase. If the collector impedance is relatively low, you might wish to tap down the coil. Choose a point from ¼ to ½ down. Collector impedance of a bipolar transistor is generally higher than the base impedance of the following stage.

Let's say you decide on a point ⅓ down the number of coil turns. Now comes the real loading, getting energy from this tank circuit into the base of the following stage. The base tap will be much closer to the bottom or low impedance point of the coil. Place it ½ turn up from ground. Generally at this point it takes somewhat sophisticated equipment to determine what is truly happening.

A sweep frequency signal generator, a calibrated marker generator, and a spectrum analyzer are used in the design laboratory. But when these are not available, there are other ways to make a satisfactory measurement. An RF vacuum tube voltmeter can really help.

Sending a steady signal into the receiver and using some type of indicator, possibly an S-meter on the transceiver, the capacitor is tuned to resonance. If the tuning is sharp, you know the bandwidth will be limited. Tapping the base further up on the coil will load the coil more heavily, and cut down the selectivity, because the tuning will be broader, and the receiver will cover a wider frequency range. One point: the further down the coil (toward ground) that you place the collector tap, the more stable the circuit; but circuit gain will be reduced. ■

TS-940/Transverter Jack-Pin numbers

8-pin DIN pin number	Function
1	Ground
2	PTT to transverter (12VDC @ 50 mA max.)
3	Ground
4	TS-940 Final Amplifier disable (Ground from transverter)
5	Received (input) signal from transverter
6	ALC from TS-940 (not used here)
7	Transmitted (output) signal to transverter
8	Internal TS-940 HF signal—connect to pin 5 to restore TS-940 HF when transverter off.

Table 4.