Build It Yourself from *QST*

Part 2: Now that you've gotten the parts, here's how to build your project using ground-plane construction.

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In Part 1, we ordered the parts for the 20-meter version of Zack Lau's QRP transmitter.[3] This transmitter is a great first project—you can build it even if you've never used a soldering iron. You should have a nice pile of parts by now, and this month we're going to put them together using a construction technique called *ground-plane construction*. If you've decided to build your 20-meter transmitter using the FAR Circuits board,[4] I suggest sticking with us this month, because I'll cover transistor pinouts and other component information you'll need in completing your PC-board transmitter.

Ground-Plane Construction Overview

Ground-plane, sometimes called *ugly* construction, is simple: You build the circuit on an unetched piece of copper-clad circuit board. Wherever a component connects to ground, you solder it to the copper board. Ungrounded connections between components are made point to point.

Once you learn how to build with a ground-plane board, you can grab a piece of circuit board and start building any time you see an interesting circuit. It's easy to trace and modify a ground-plane-built circuit. Ham designers generally also find that building on a large copper ground plane makes most MF/HF circuits more stable than building them on a PC board—at least until the PC-board version goes through several iterations to cure circuit instabilities!

Building a ground-plane board is fun, and I think it's more rewarding than simply stuffing and soldering a PC board. Ground-plane construction is something like model building, connecting parts using solder almost—but not exactly—like glue. Because you build the circuit directly from the schematic, ground-plane construction can help you get familiar with a circuit and how it works much better than etched-PC-board construction can.

Ground-plane construction is very flexible because you can build subsections of a large circuit as small ground-plane modules and string them together into a larger design. The prototype of Dave Newkirk's 10/18 receiver (Fig 7 in Chapter 30 of the 1992 *ARRL Handbook*) is a good example of this design technique. I've used an audio amplifier from one receiver design and combined it with a VFO circuit and mixer from two other designs, all built on individual ground-plane boards. Once I had the audio amp and VFO working, I modified the mixer board until I was satisfied. This is a great way to learn about electronics!

Don't be bashful about how your ground-plane projects look. Your transmitter probably won't look as slick as an etched-PC-board circuit or factory-produced rig. It'll probably look more like Part 1's Fig 2A! Part of the philosophy behind ground-plane construction is that you don't have to build "pretty" to build radio gear that's first-rate in ruggedness and performance. The important part is how well your circuit works—don't worry about how it looks. Remember, ground-plane and etched-PC-board versions of a circuit that give the same electronic performance both "look" the same *on the air.* Building is supposed to be *fun.*

Tools

Soldering is the foundation of ground-plane construction, so you'll need a soldering iron. It needs to be hot enough to do the job, and small and lightweight enough for agility and comfort. A 100-watt soldering gun, for instance, is overkill, but any iron in the 15- to 45-watt range should work. (A temperature-controlled iron is also okay. These cost more than they're worth for occasional projects, though.) I used a 30-watt soldering iron from Radio Shack (part #64-2067) to build this transmitter. Get an iron with (or that can be equipped with) a small conical or chisel-shaped tip. If this is your first time with a soldering iron, see the "Soldering Basics" sidebar for how to get started in soldering.

You'll also need a pair of needle-nose pliers to bend component leads, and a pair of diagonal cutters to clip the leads. Wire strippers are handy, but you can strip wire with a knife if you're careful. You can also use the knife to scrape off magnet-wire insulation. I use my Swiss Army knife. A package of "clip leads" (short wires with alligator clips on both ends, Radio Shack #278-1156) will come in handy when you start testing the board, especially if you get impatient and want to test your transmitter before you put it in the box. (After completing a project, I usually end up making at least my first contact with the circuit board buried under an amazing pile of clip leads.)

Laying Out the Circuit

Because you wire your circuit instead of following an etched circuit pattern, you can build it however you like. Here are a few guidelines that will help your transmitter work well:

- Avoid laying out circuits that filter or amplify so their outputs end up near their inputs. With our transmitter, this means that the antenna connection should be made on the opposite side of the board from the VXO components. It also means that the buffer amplifier's output shouldn't double back to be near its input, or near the VXO. If a stage's output is too near a previous stage's input, the output signal can *feed back* into the input and cause problems. Building a filter's output too near its input may allow signals to leak around the filter.
- Keep component leads as short as practical. I didn't say "as short as *possible*"—just keep lead length in mind. You'll have to clip component leads shorter than their untrimmed lengths—that's what the diagonal cutters are for. Don't clip them off 1/16 inch from the component body, but don't leave them 1-1/2 inches long, either.
- Remember that metal transistor cases conduct, and that a transistor's metal case is usually connected to one of its leads (most commonly, in bipolar junction transistors, the collector). Because of this, it's a good idea to keep the case away from other components. Also, don't let the case touch the ground plane unless you're sure the case can

3Notes appear on page 39.

Soldering Basics

You can build the 20-meter VXO transmitter using ground-plane construction even if you've never used a soldering iron before. You don't need an expensive iron—I used a 30-watt Radio Shack iron (64-2067, $4.79 in the 1992 catalog). Don't try to use a soldering gun, though; you'll melt components. Here are a few more tips:

Keep everything *clean*. When you let the iron sit between making solder joints, the old solder vaporizes and leaves impurities on the iron tip. These appear as black gummy junk on the tip. You don't want this in your next solder joint, so keep a damp sponge near the iron and use it to wipe off the tip just before you apply it to a solder joint. You can keep the sponge in an empty sardine can or any other container that will keep the water off your workbench. The Radio Shack soldering iron holder (part #64-2078) combines a stand for the hot iron with a sponge for cleaning the tip. You'll see soldering-iron holders like this in other catalogs as well.

Clean the component leads, too. If a component's leads look dull and slightly corroded, scrape or steel-wool the leads bright before you solder them into the circuit. Resistor leads are prime candidates—they can sometimes be almost black from oxidation, and the oxide on the leads will prevent solder from making a good electrical connection. (Keep the steel wool away from your circuit board—you don't want pieces of steel wool to fall into the circuit and cause short circuits.)

Heat the solder joint, not the solder. Apply the iron to one side of the connection, let the connection heat for a second, and then apply the solder to the other side of the joint (see Fig A). Don't try to melt the solder and let it drip onto the connection; it's not glue. Good soldering actually forms *alloys* at the interface between ground-plane copper and solder, and solder and component lead metal. (This is why copper soldering tips slowly dissolve away over weeks of soldering. They actually contribute a little copper to every joint they solder!)

When you solder a lead to the ground-plane circuit board, press the lead between the iron tip and the board. Wait a second or two for the board to heat up, and then flow the solder between the iron tip and the board. Make sure you heat the component lead *and* the circuit board, or the solder's surface tension will keep it lying on top of the board in a big glob.

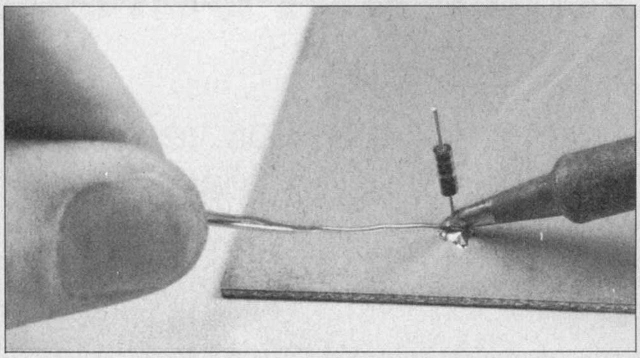

Fig A—Apply the soldering iron to the connection, wait a second or two for the joint to heat up, and then apply the solder from the other side. (*All photos, except Fig 7, by Kirk Kleinschmidt, NTØZ*)

Don't use acid-core solder; that's for plumbing. Use only *rosin-core* (sometimes called *electronics*) solder. I like to use thin (0.032-inch-diameter) solder. Thin solder makes it easier to use just enough solder for each connection. Thicker solder sometimes melts all over everything and overloads joints.

If you're unsure of your soldering skills, make tighter mechanical connections between components. That way, you won't be relying on the solder to make a mechanical bond as well as an electrical connection. Once you get a little practice, you can use the "side-by-side lead" techniques described in the article.

Don't get discouraged if your first soldering efforts look like they were done by a gorilla with a blowtorch. Like any skill, soldering takes practice. You'll get better at it as you build more projects. (That's a not-too-subtle hint to *keep building!*)—*KB1MW*

For more about soldering, see B. Bergeron, "Making Soldering Safer," *QST*, Mar 1991, pp 28-30. Also see G. Myers, "More on Making Soldering Safer," Technical Correspondence, *QST*, Aug 1991, p 42, and Chapter 24 of the 1992 *ARRL Handbook*.

be grounded. (More later on how to ensure this.) This also applies to metal heat sinks in direct contact with metal transistor cases.

Getting Started

Before you start soldering, make sure your piece of circuit board will fit in the box you're going to use. It's much easier to cut the circuit board and drill its mounting holes *before* you build the circuit on it. (This sounds obvious, and it is if you think of it before you start building, but many builders, including me, have forgotten this more than once!) If you bought the circuit board and minibox from Radio Shack, cut your ground-plane board with a hacksaw to 4½ × 2½ inches. Lightly buff the copper with a piece of extra-fine steel wool. This removes any oxidation, which can make it hard to solder to the board.

QST schematics are usually drawn to begin at the left with input or oscillator circuitry and proceed toward output or antenna at the right. Thus, the easiest way to build a ground-plane circuit from *QST* articles is to lay out and build the circuit from left to right as it's shown on the schematic. (As you gain more building experience, you'll find it easy to lay out a circuit no matter how its schematic is drawn.) With our 20-meter VXO transmitter, this means we start building with the VXO (Q3 and associated components).

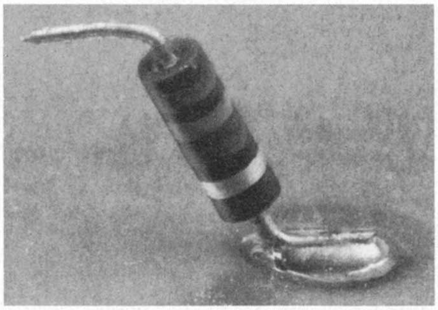

Fig 3—Cut and bend both leads of the first resistor, and then solder one lead to the ground plane.

Where to start building *in* the VXO circuit is the next decision. Because we're building ground-plane, we'll start with a *grounded* component because it supports other components above the ground-plane board.

R5—Q3's 270-Ω emitter resistor—is a good place to start. Clip its leads about ¼ inch from each end of the resistor body. Bend both ends at a 90° angle from the resistor body, and solder one end to the ground plane, about ½ inch from the board's lower left corner. This point determines where the rest of the circuit will be on the circuit board. Solder the resistor so it stands up on end, as shown in Fig 3. Use the tip of the iron to hold the lead down on the circuit board, wait a second or two for the board to heat up, and then flow the solder between the tip of the iron and the board. Put down the solder and hold the resistor *steady* by its free end. Pull the soldering iron off the joint and keep holding the resistor steady until the solder solidifies. (Movement in the solder joint during cooling can cause a poorly conductive, *cold-soldered* joint that may lead to circuit failure.) Congratulations: You've taken your first step in ground-plane construction!

Alternatively: Apply enough solder to the board to make a small (¼-inch diameter), slightly domed circle where you want the grounded component to be soldered to the board. Tin the component lead to be grounded (coat it with just enough hot solder to make it shiny). Press the tinned lead down atop the solder circle. Touch the solder iron tip against the lead and the circle to melt the solder in both. Pull the soldering iron away and hold the component *steady* by its free end until the solder solidifies.

If you come to a spot where a grounded component would simplify construction but there's no grounded component at that point in the circuit, you have two choices: You can add *terminal strips* as necessary. These are insulating strips bearing rows of solder lugs; the foot of one or two lugs in a strip can be screwed or soldered to the ground plane to hold the strip in place. Radio Shack carries five-lug strips (#274-688); and other suppliers carry them in wider variety.

A Power Supply for the Transmitter

The transmitter needs a source of 12 to 13.8 volts at around 250 milliamps. You can use batteries, but a regulated, ac-operated 12-V power supply is a handy accessory, especially if you plan to build any other simple transmitters or receivers. Radio Shack and other suppliers carry small 12- or 13.8-V regulated supplies capable of providing 2 to 6 amps or so; these generally cost in the $30 to $50 range. If you need only 1 ampere or less, building your own supply can save you money *and* provide building experience. Such a power supply is very simple, so it's a great first project and good soldering practice.

The circuit (Fig A) uses a 7812 three-terminal regulator; you'll find it and all the other parts at Radio Shack for around $30. This power supply can provide about an ampere of regulated 12-V dc. I used ground-plane construction techniques, as discussed in the article. Use a small amount of heat-sink grease on the back of the regulator. No insulator is needed between the regulator case and box top.—*KB1MW*

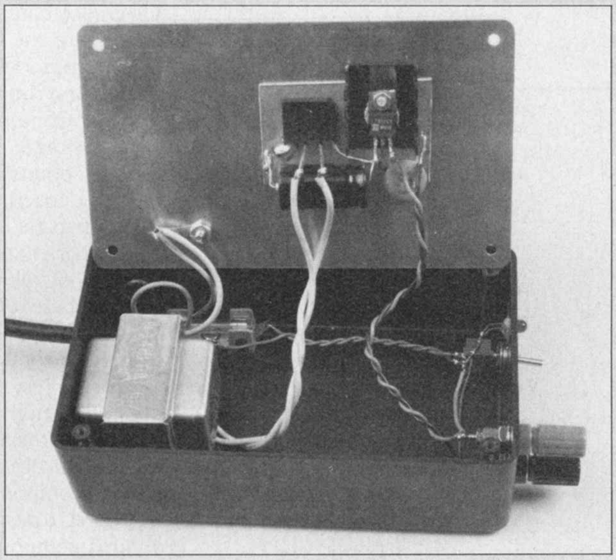

Fig B—Power-supply construction. Be sure to wire the fuseholder in series with the line cord's *black* (*hot* or *live*) wire. Connect the cordset's *green* (ground) wire to the power transformer's metal case, the box's aluminum cover, and the regulator circuit's negative wire. This circuit uses an electrolytic capacitor (C1), which is polarized. Be sure to connect C1's + and − leads correctly.

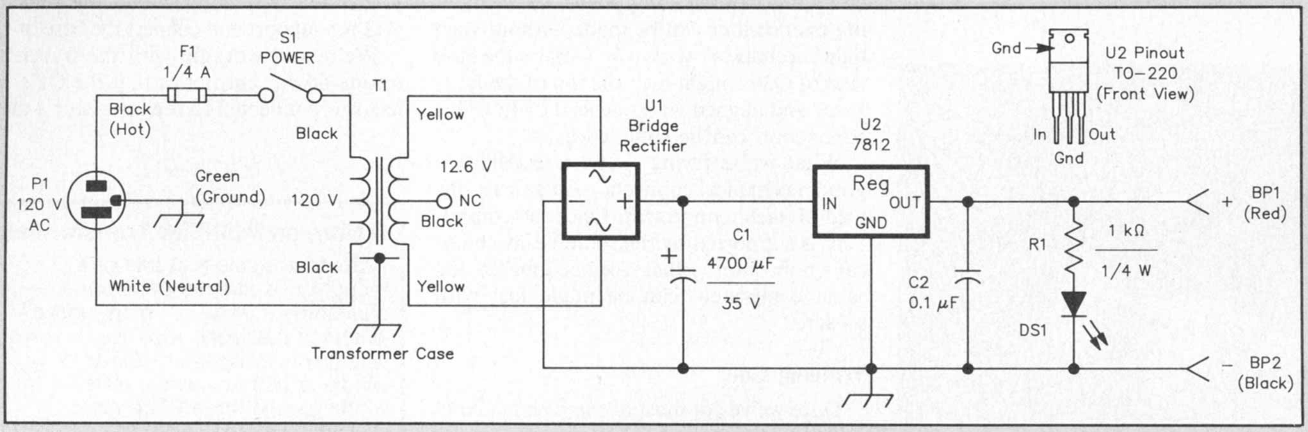

Fig A—All of the power-supply parts are available at Radio Shack. Wall-socket power is dangerous, so wire your supply carefully. Don't work on the power supply wiring while the supply is plugged into the wall—unplug the supply first. If in doubt, have your wiring checked by an experienced equipment builder before plugging in the supply. All the part numbers listed are Radio Shack; other suppliers carry suitable equivalents.

BP1, BP2—Nylon binding posts (274-662).
C1—4700-µF, 35-V electrolytic (272-1022).
C2—0.1-µF, 50-V disc ceramic (272-135).
DS1—Jumbo red LED (276-041).
F1—¼-A, 250-V fuse (270-1270) in chassis-mount holder (270-739).
P1—Three-wire ac cordset (278-1258).
R1—1-kΩ, ¼-W resistor (271-1321).
S1—Subminiature SPST toggle switch (275-612).
T1—Transformer: 120 V ac input, 12.6 V (center-tapped), 1.2 A output (273-1352).
U1—50-PIV, 4-A bridge rectifier (276-1146).
U2—7812 voltage-regulator IC (276-1771).
Miscellaneous—TO-220 heat sink (276-1363); 6¼ × 3¾ × 2 inch project box (270-627).

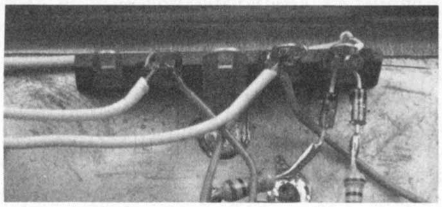

Fig 4—A terminal strip can anchor floating components or wire ends where no grounded circuit component exists to do the job. High-value resistors can also be used to do this.

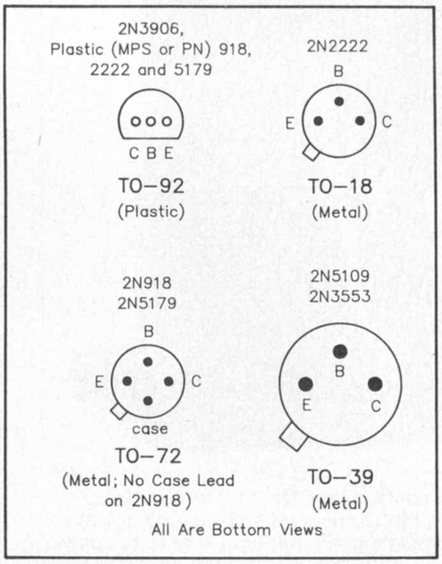

Fig 5—Pinout for the transistors used in the 20-meter VXO transmitter. The electronics industry identifies transistor cases with standardized designators that begin with *TO* (for *transistor outline*).

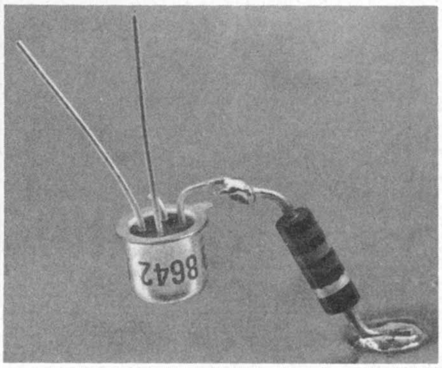

Fig 6—The first lead of each component must make a firm mechanical connection. Bend the emitter lead of Q3 and crimp it over the resistor lead before you solder it. Notice that the case lead of this 2N5179 is clipped off at the transistor. In the 20-meter VXO transmitter, this lead can be clipped or connected to ground—it doesn't matter. The plastic version of the 2N5179 has no case lead. When a device comes in different cases, thorough authors will tell you whether or not case type makes a difference. Some transistors first released only in metal-cased form are now available in plastic cases.

Fig 4 shows how I used a miniature five-lug strip to anchor **SPOT** switch and keying connections to my transmitter board. Or you can add a grounded component that has little or no effect on the circuit. High-value resistors—470 kΩ and higher for circuits operating at and below 28 V—will work for this because (in most cases) they'll draw so little current that the circuit will operate as if they aren't there.

Junction Points

Grounded components run from the circuit down to the ground plane, and other two-lead components (such as capacitors and resistors) run from one circuit point to the next. Components with more leads (transistors and transformers) determine "junction points" where several components come together. Work from one junction point to the next.

I like to orient transistors so that it's easy to remember which lead is which. Most transistor base diagrams show the leads from the bottom (Fig 5), so it's easiest to mount transistors bottom up. It's also easier to solder the rest of the components to the transistor when it's got its leads sticking up in the air—otherwise you have to try to work underneath the transistor to connect the other components.

The first transistor lead soldered to a grounded component must be crimped to the component lead to support the transistor. Use the needle-nose pliers to make a small hook in the transistor lead and pinch it over the resistor lead. Once you've got a good mechanical connection, you can solder the components. Fig 6 shows the emitter of Q3 soldered to R5.

When you've got the transistor supported by a grounded component, the remaining connections can be made without such tight mechanical work. Fig 7 shows the base lead of Q3 brought over the top of the transistor and aligned with one lead of R6. This connection can be soldered as is.

What we're trying to do is establish a good mechanical connection on at least one lead of each component. Once the component is supported by the soldered mechanical connection, other connections to the same component can be made just with solder.

Winding Coils

Once we've got most of the junction components mounted at Q3, we move over to the next junction, T1. This coil has five leads, so it must be mounted carefully so that all of its connections point in the right direction. T1's primary winding has 20 turns. When you wind toroids, remember that just sticking the wire through the core counts as "one turn." Wrapping the wire around the core and passing it back through the core is two turns. You can count the number of turns by counting the number of times the wire passes through the center of the coil. When you get to the 13th turn, twist

Fig 7—Once a component is firmly supported, you can make further connections without crimping. Just solder the leads as they lie side by side. This 2N5179 has its case lead grounded.

the wire together about 1/8 inch from the core to make a tap point, as shown in Fig 8. Use a knife to scrape the insulation off the wire before you solder it into the circuit. Wind the secondary over the primary winding, *in the same rotational direction.*

The dots on the schematic show you how the windings are oriented, or phased, relative to each other. Concerning T1 in Fig 1, the dots tell you to connect the start of the primary to the collector of Q3 and the start of the secondary to the junction of R9 and R10. Fig 8 details the windings of T1 and T2.

Moving On

Use R9 to support T1, and then use R10 to determine where you put the base of Q4. Solder the base connection, and then use R12 for support and connect the base of Q5.

We're still working with the transistors upside-down, but notice that the Q5's collector is connected to the transistor's metal

A Note on Multifilar Transformers

Some projects (not this one, though) use toroidal transformers containing *multifilar*—"many wired"—windings that consist of two or more wires wound together. (*Bifilar* windings use two wires, *trifilar* windings use three.) The most practical way to wind such transformers is to twist their wires together (at a pitch of 5 to 10 twists per inch) and wind all of the wires at once. Paint the wires before winding to tell which is which, or make continuity checks with an ohmmeter to sort out which winding start goes with which end. Wire multifilar transformers into your circuit carefully to ensure that each winding is connected to the proper points in the proper phase.—*WJ1Z*

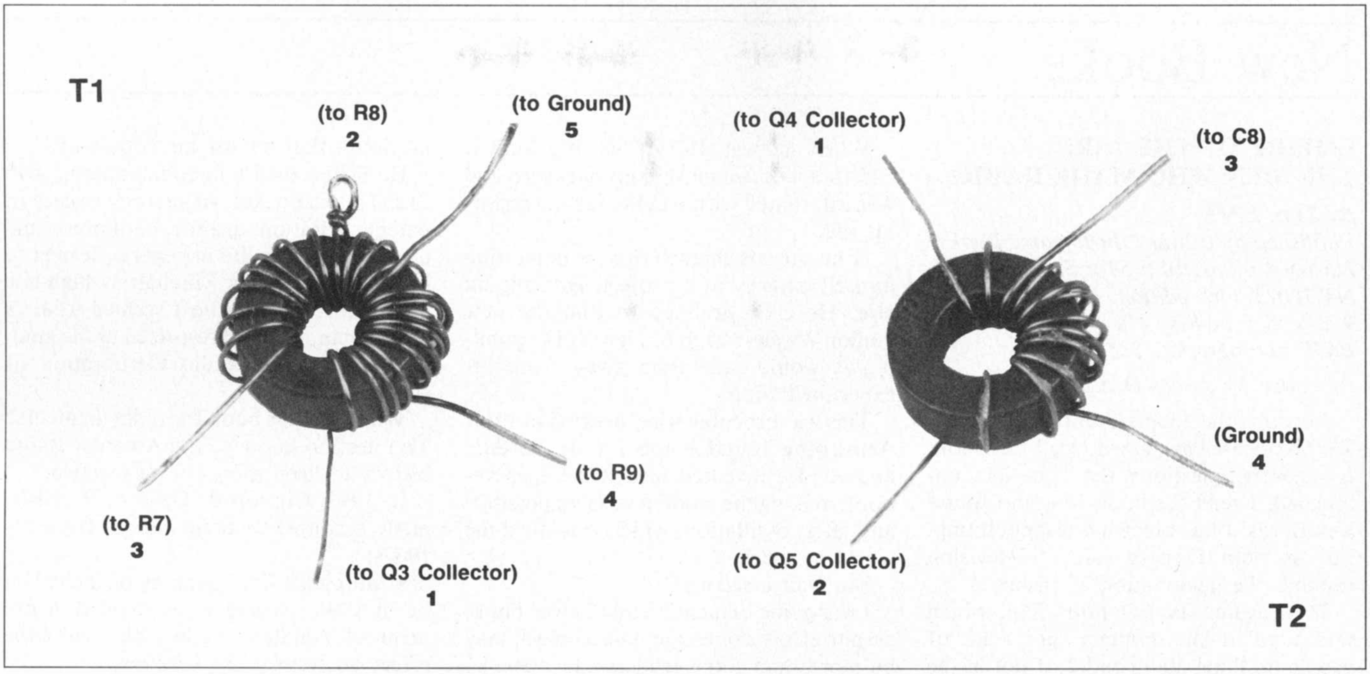

Fig 8—The dots on the schematic show how the coil windings are phased. Twist the wire a few times to form the tap on T1. As is true of the coil ends, you'll need to scrape the insulation off the twisted wires so you can solder to them.

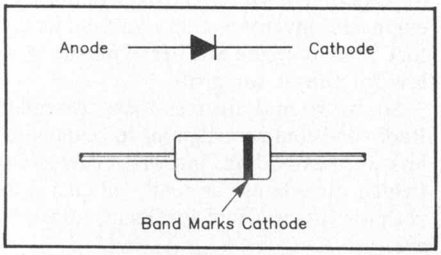

Fig 9—The line on the diode case marks the cathode. The arrowhead in the diode schematic symbol points to the cathode.

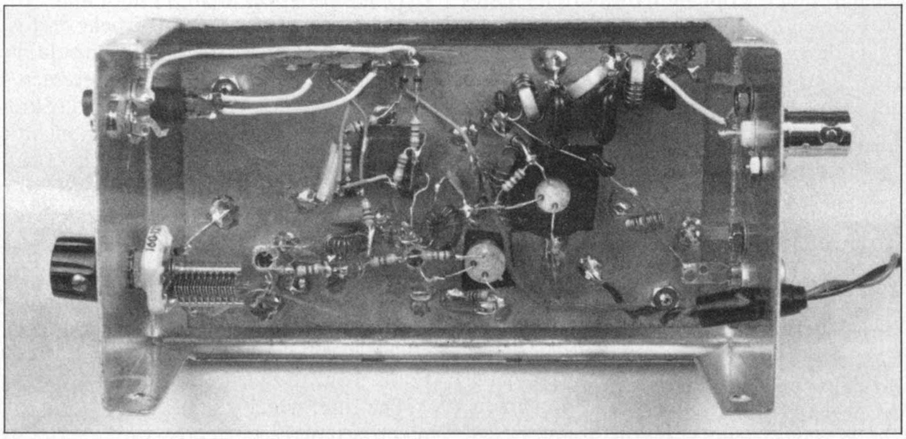

Fig 10—Here's my completed ground-plane transmitter, mounted in a minibox. If you're in a hurry to get your 20-meter transmitter on the air, you don't even need a box—this circuit doesn't need a lot of shielding with most antennas. Fig 2A (in Part 1) shows Zack Lau's prototype—he soldered both the BNC **ANTENNA** connector and VXO **FREQUENCY** capacitor to the circuit board, and connected the power supply and key with clip leads. (You can also use a short length of RG-174 coax to attach the **ANTENNA** connector, and connect the **KEY** and **POWER** jacks with short wires.) When I first completed *my* transmitter board, I had it working on my bench next to a ground-plane version of Zack's receiver under a mess of clip leads. You can use the transmitter like this, but eventually you'll probably want to put it in a box.

case. If we let the case touch the ground plane, we'll connect the collector to ground. This will cause excessive power supply current to flow through Q2 and T2, possibly destroying Q2, when we key the transmitter. Put a piece of electrical tape on the circuit board to insulate Q5 from the board. You'll have to do this for Q6 as well (and Q4, if you use a metal-cased 2N2222 there). Q6 also needs a heat sink. Put a *little* heat-sink grease on the outside of the transistor case before you slide the heat sink onto the transistor. (I haven't yet found a way to use heat sink grease without getting it all over my fingers.)

When you install the circuit's diodes, use Fig 9 for a guide—the line on a diode's case marks its cathode. Diodes won't work properly if you put them in backwards.

Work from one transistor to the next, and you'll be done before you know it. Check your wiring carefully. One way to do this is to use a photocopy of the schematic and mark each lead on the schematic with a red *X* when you've verified that it's connected to the right spot in your circuit. Fig 10 shows my completed ground-plane transmitter board.

Summary, Part 2

In this article, I've described ground-plane construction, an increasingly popular building technique that's useful for prototyping and completed ham projects alike. You've got a project waiting to be powered up and tested if you built the ground-plane version. How about checking and rechecking your wiring a few more times?

PC-board builders, I'll be talking to you next month. (Ground-plane builders, you're invited, too, because we'll also look next month at ground-planing a sidetone oscillator.) Once everyone has a complete transmitter board, we'll put the boards into boxes, test them, and get them on the air.

Notes

[3]B. Hale, "Build it Yourself from *QST*," *Part 1*, *QST*, Apr 1992, pp 31-36.

[4]See Note 2.